Micro-CHP in the United States

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Literature Search

- Technologies Identified
  - Stirling Engine-Generator (UK)
  - Residential Fuel Cell (UK)
  - IC Engine-Generator (Japan)
  - Steam Generator Topping Cycle (US)
- Operating Strategy
  - Track thermal load
  - Excess power to grid via net metering

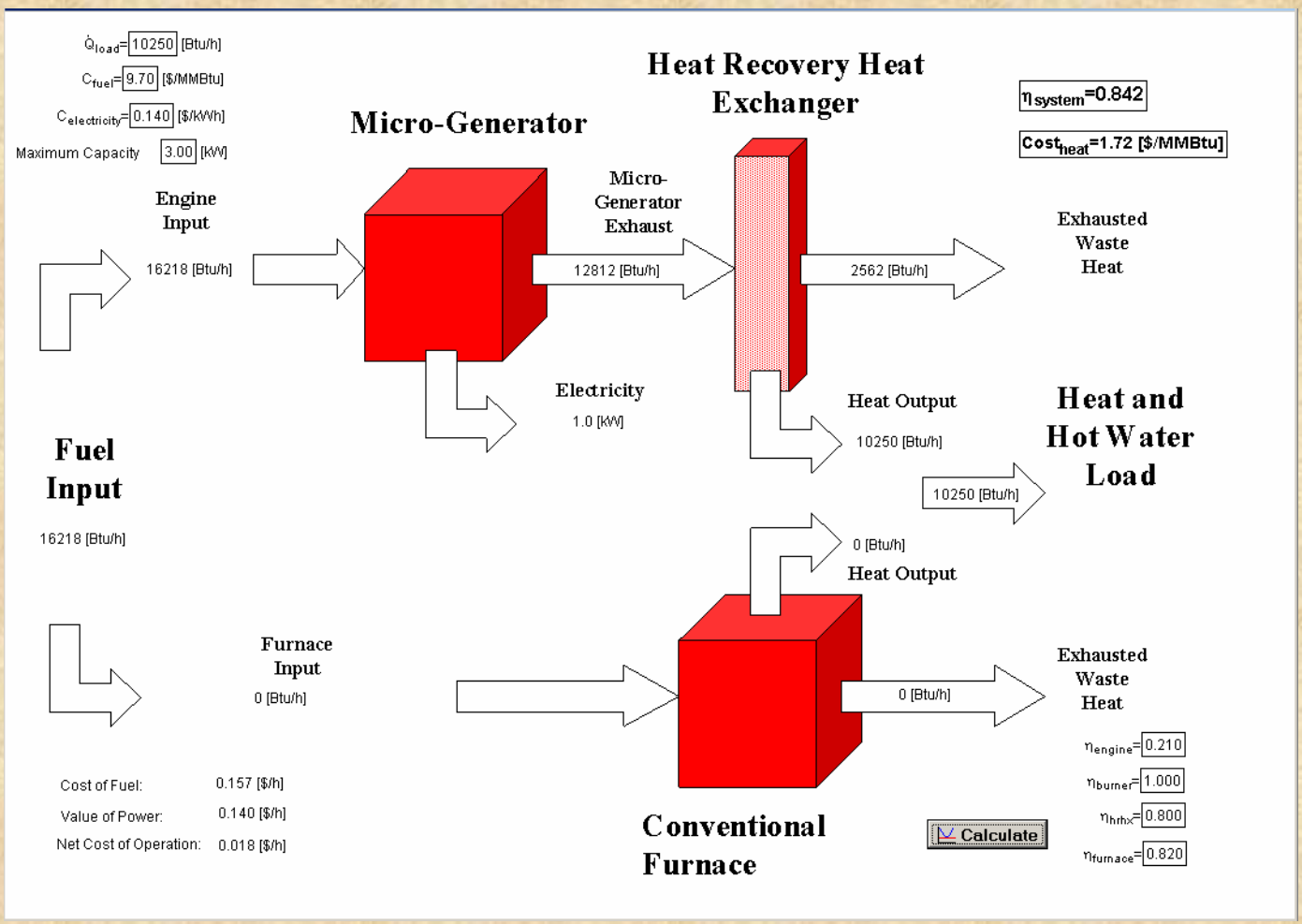
Analysis: Data & Sources

- Energy Information Administration
  - State-wide average residential fuel and electricity costs
  - Residential heating energy consumption
    - Seven census regions
    - Four most populous states
- ASHRAE
  - Heating degree days for 286 U.S. cities
- Internet
  - Heating degree days for 18 regions in U.K.
  - One electric and one gas/fuel rate in U.K.

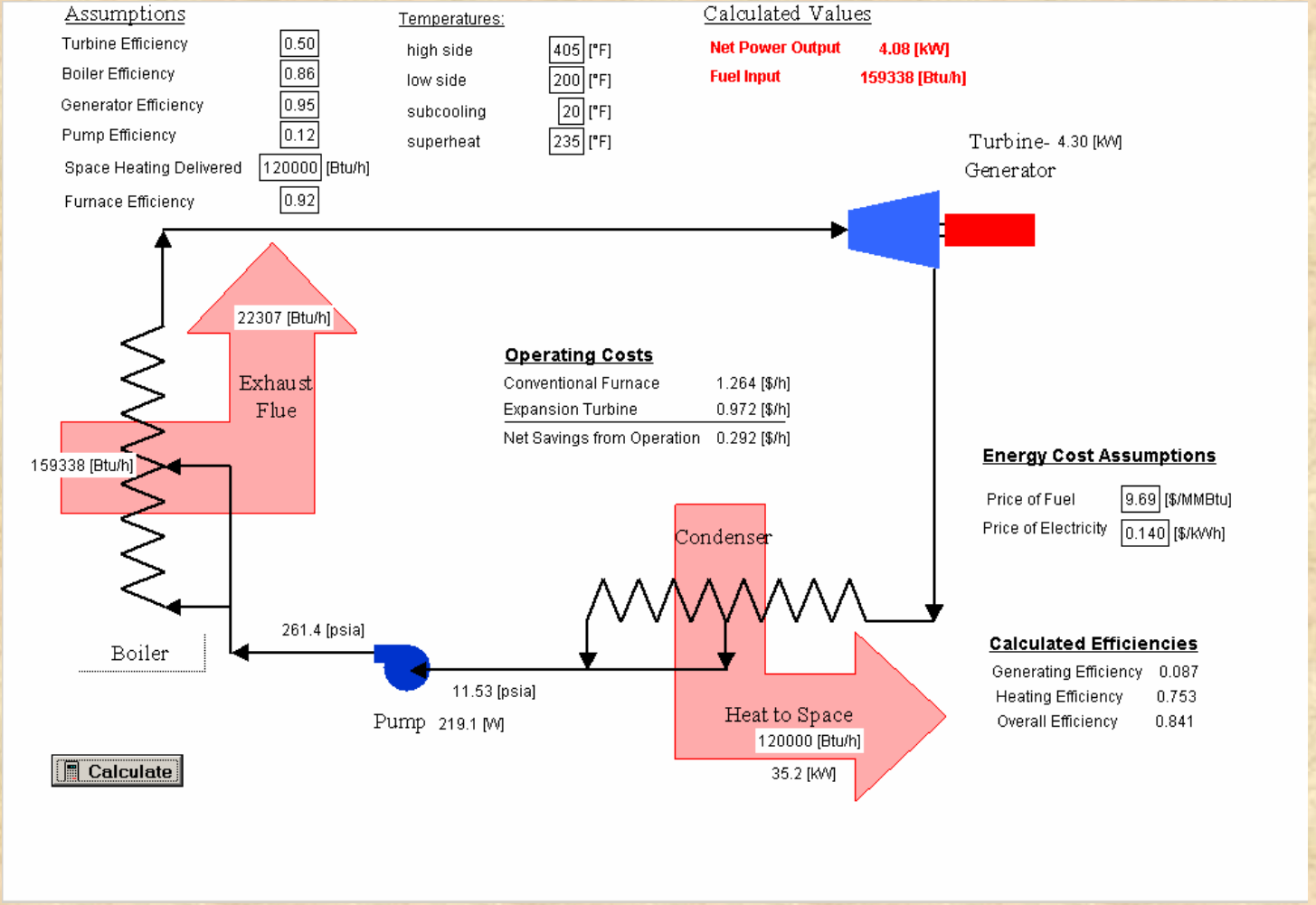
Analysis: Micro-CHP Assumptions

Parameter	Stirling Engine-Generator	Fuel Cell	Steam Generator Topping Cycle
baseline	Std Furnace	Std Furnace	High Eff. Furnace
$\eta_{baseline\ furnace/boiler}$	0.65	0.65	0.92
Incremental First Cost	$1270 / kW	$1500 / kW	$1000
O&M Costs	$0 / year	$150 / kW / year	$100 / 5000 hrs
η_{engine}	0.25	0.40	---
η_{burner}	1.00	1.00	---
ε_{HRHX}	0.60	0.45	---
$\eta_{steam\ turbine}$	---	---	0.50
$\Delta T_{approach}$	---	---	60°F

Stirling-Engine Generator or Fuel Cell with Supplemental Gas Burner



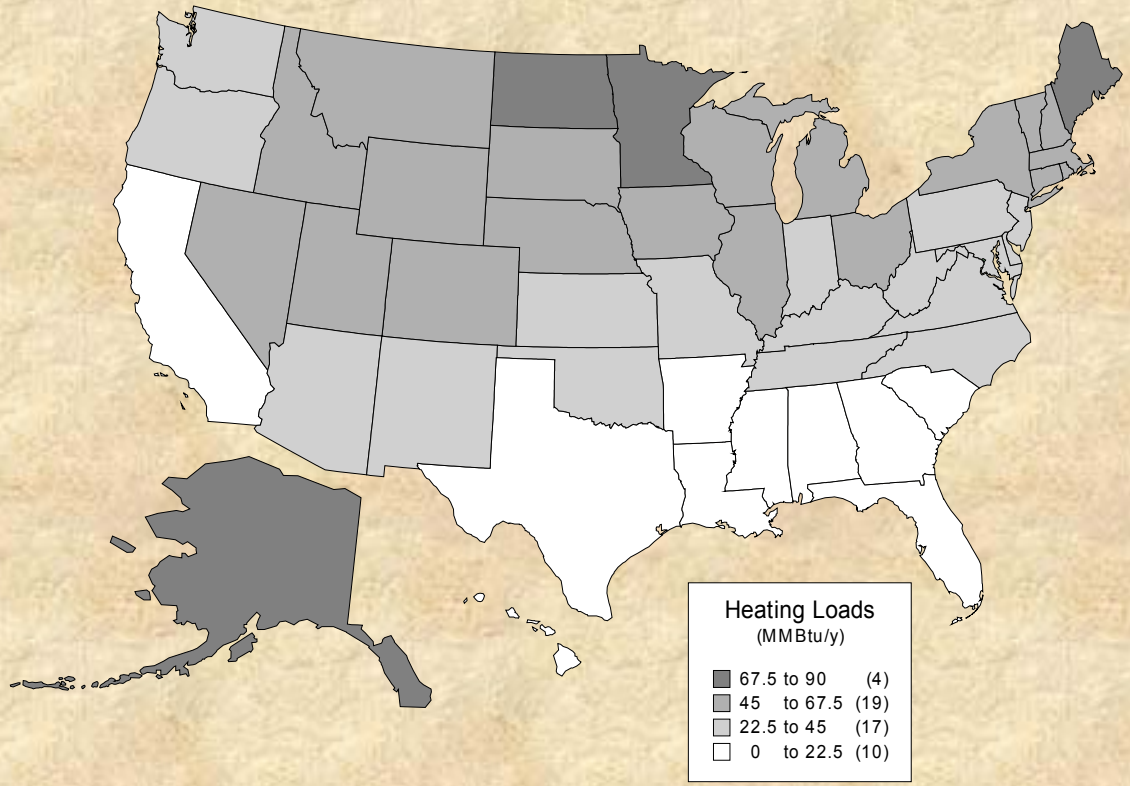
Steam Turbine Topping Cycle



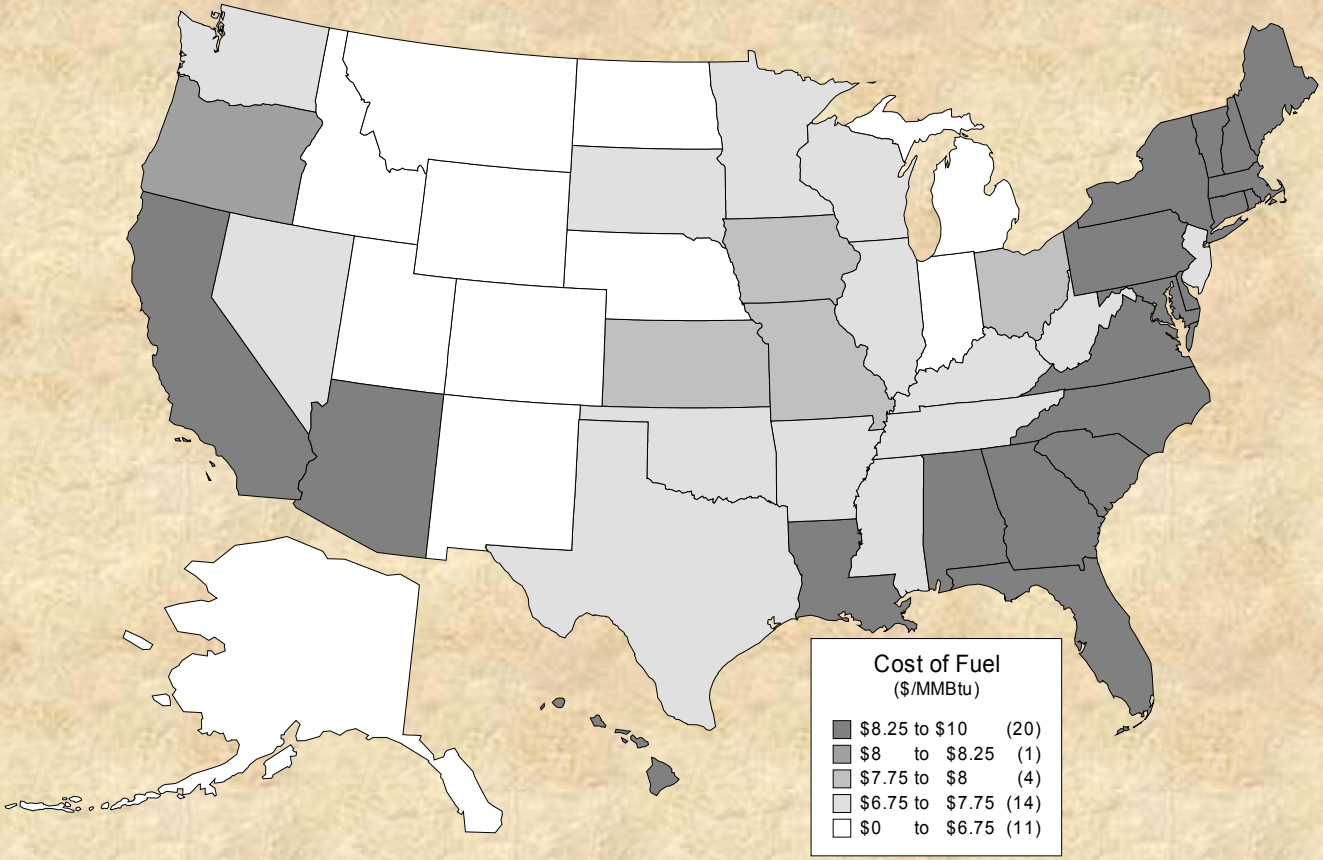
Results:

- Stirling Engine & Steam Topping Cycle
  - Modeling results consistent with references
  - Simple payback less than 10 years only in New England, New York, and Alaska
  - Payback primarily dependent on electric cost
- Fuel Cell
  - Simple payback less than 12 years only in Alaska
  - Less than 25 years in Alaska, New York, Vermont, and Michigan

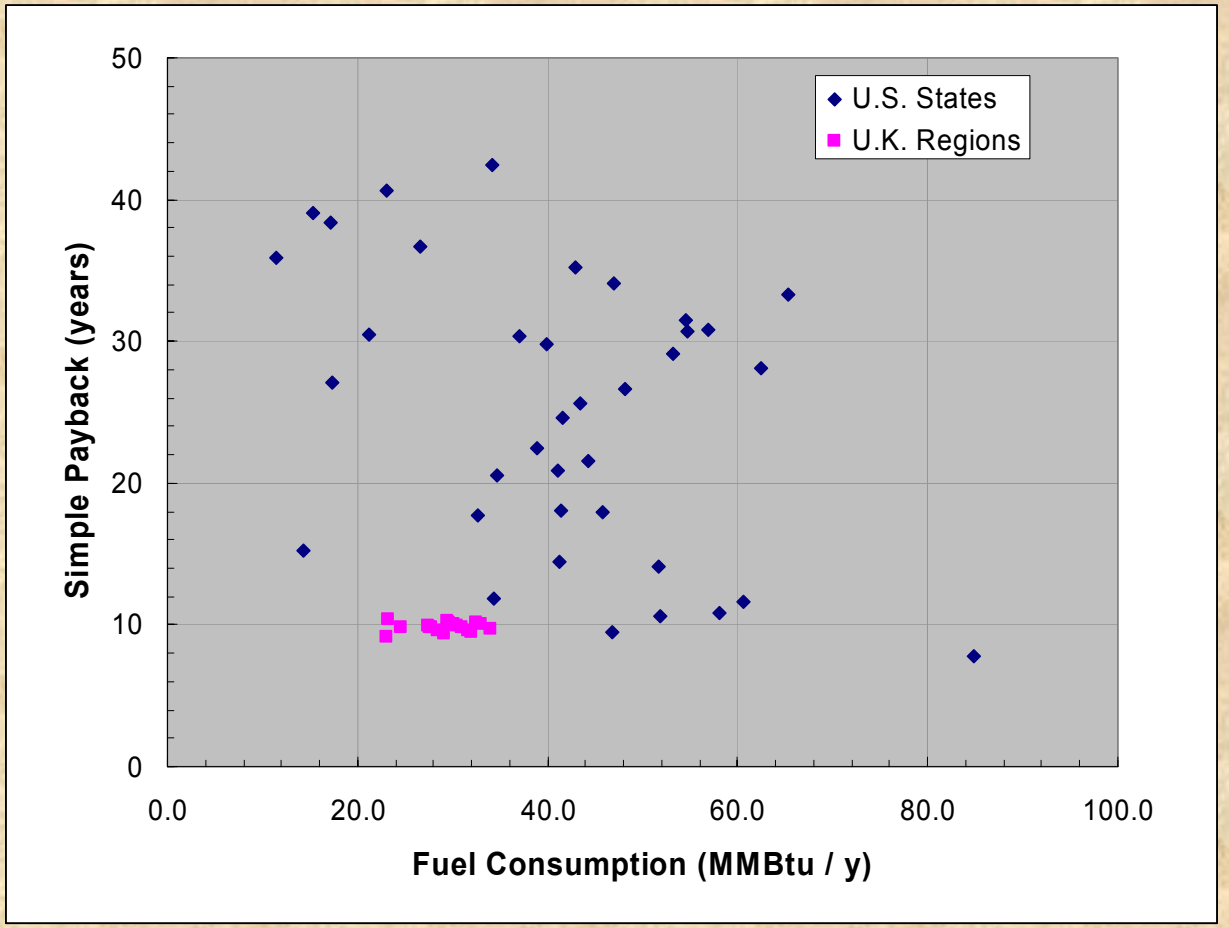
Average Household Heating Loads



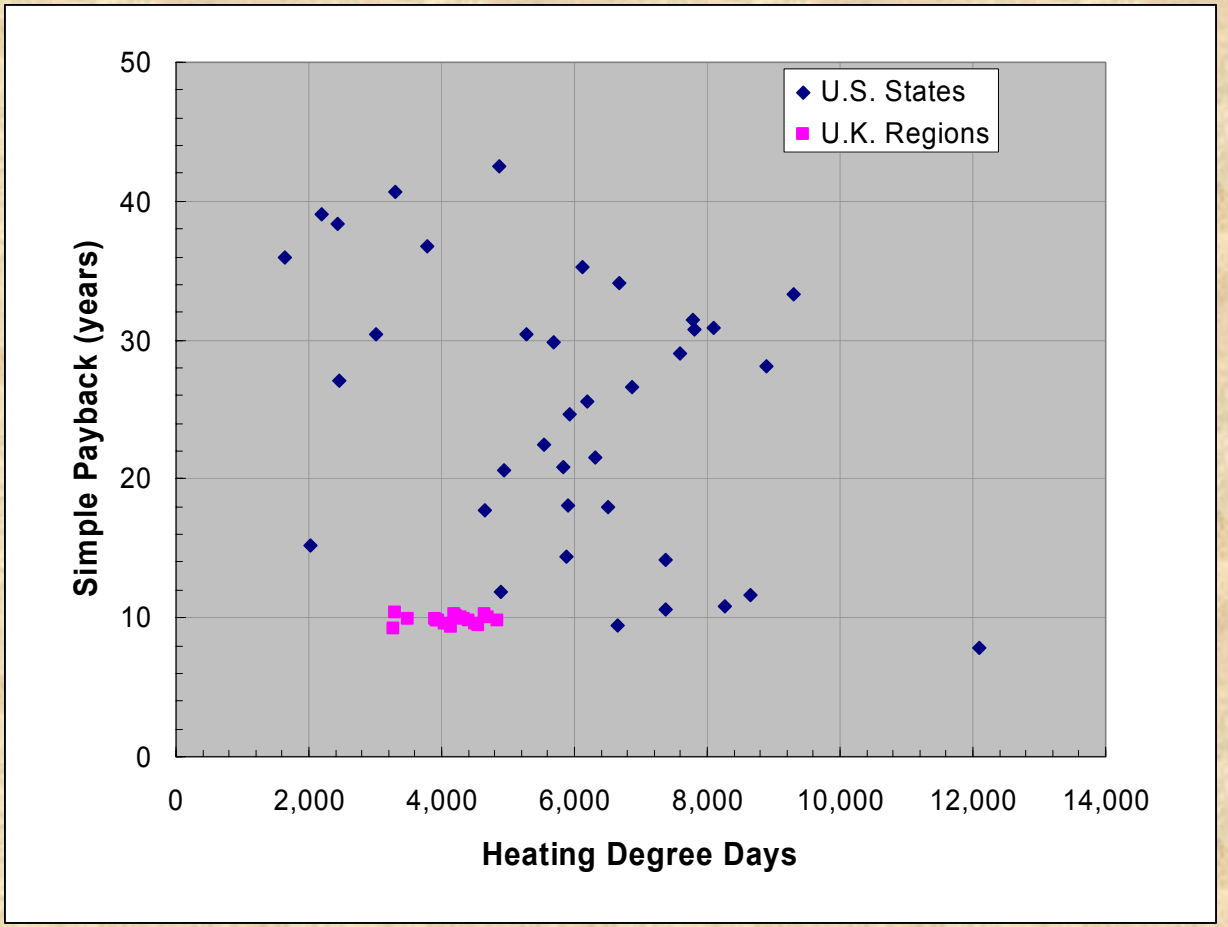
Cost of Fuel


Cost of Fuel
($/MMBtu)
$8.25 to $10 (20)
$8 to $8.25 (1)
$7.75 to $8 (4)
$6.75 to $7.75 (14)
$0 to $6.75 (11)

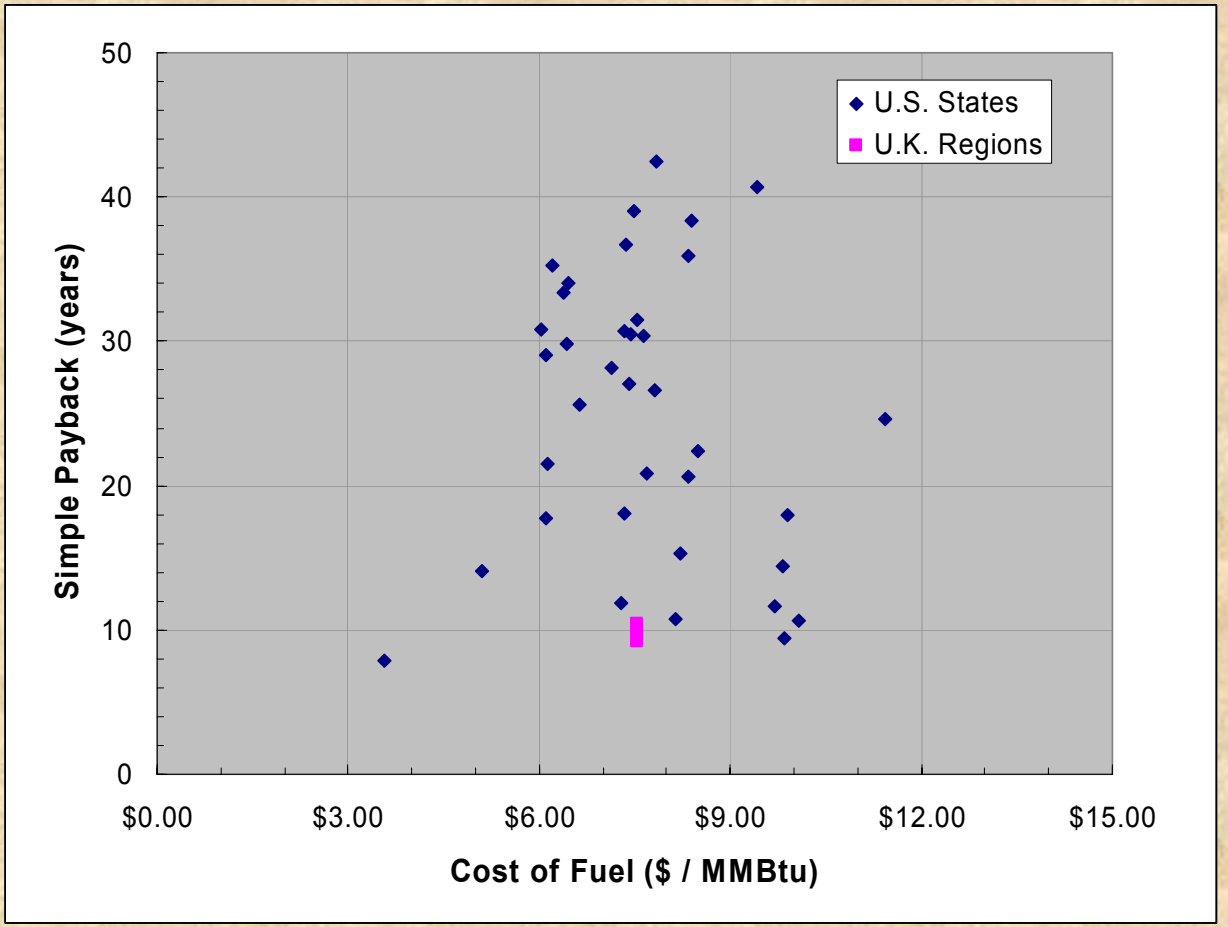
Simple Payback and Fuel Consumption



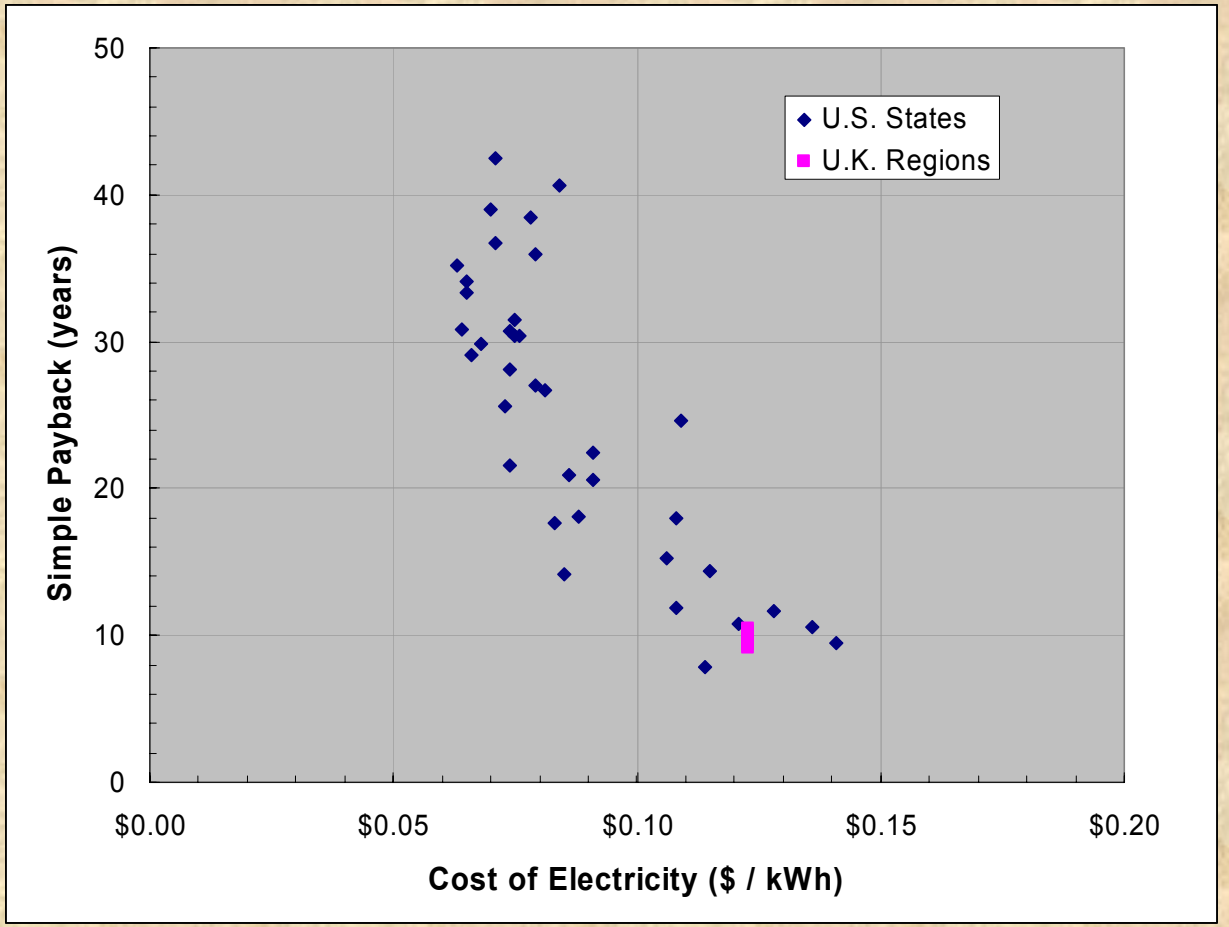
Simple Payback and HDD



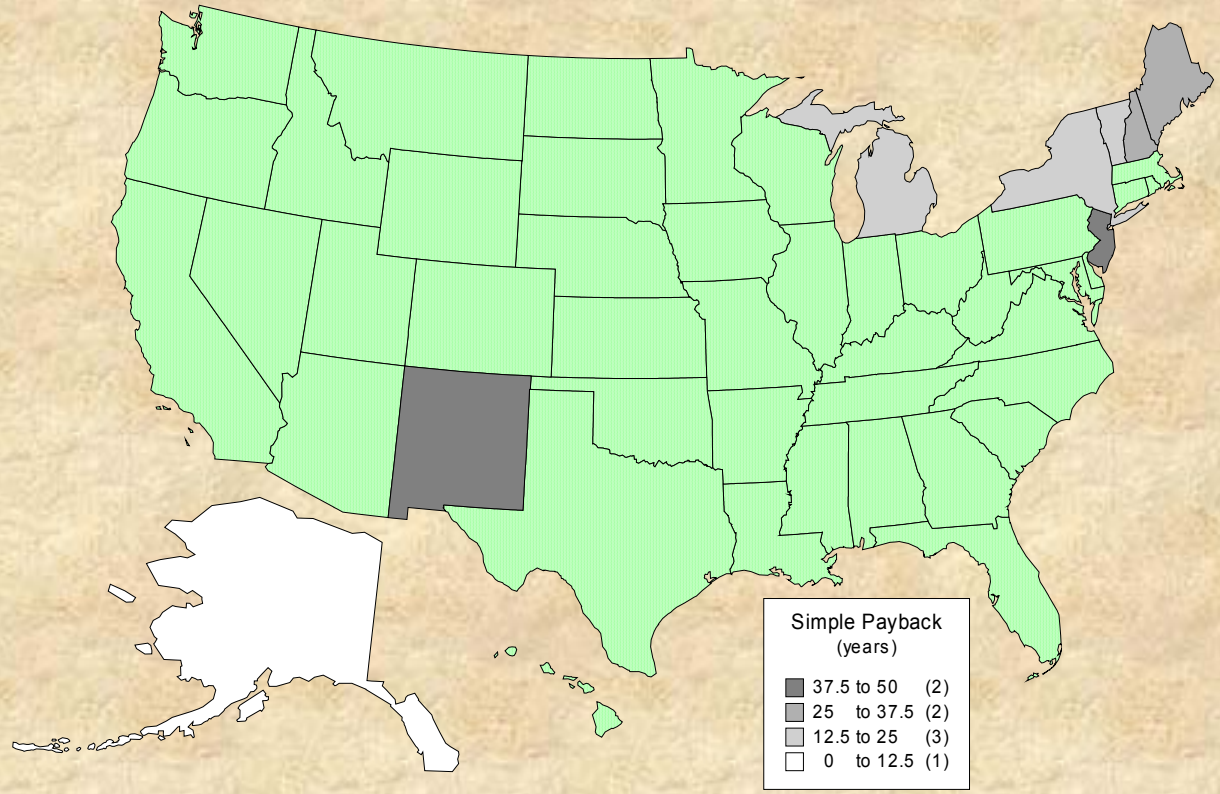
Cost of Fuel


U.S. States
U.K. Regions
Simple Payback (years)
50
40
30
20
10
0
$0.00
$3.00
$6.00
$9.00
$12.00
$15.00
Cost of Fuel ($ / MMBtu)

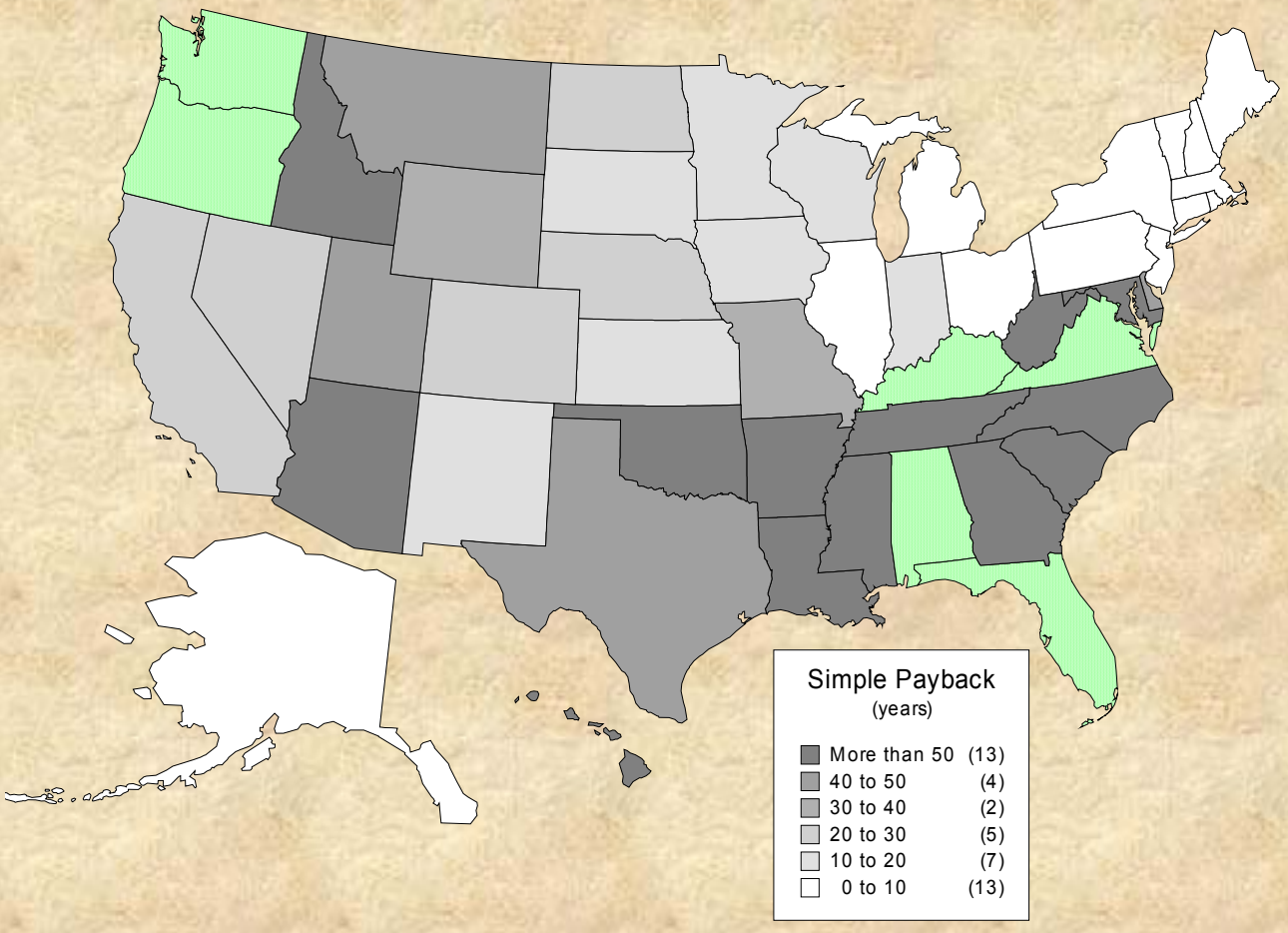
Payback vs. Cost of Electricity



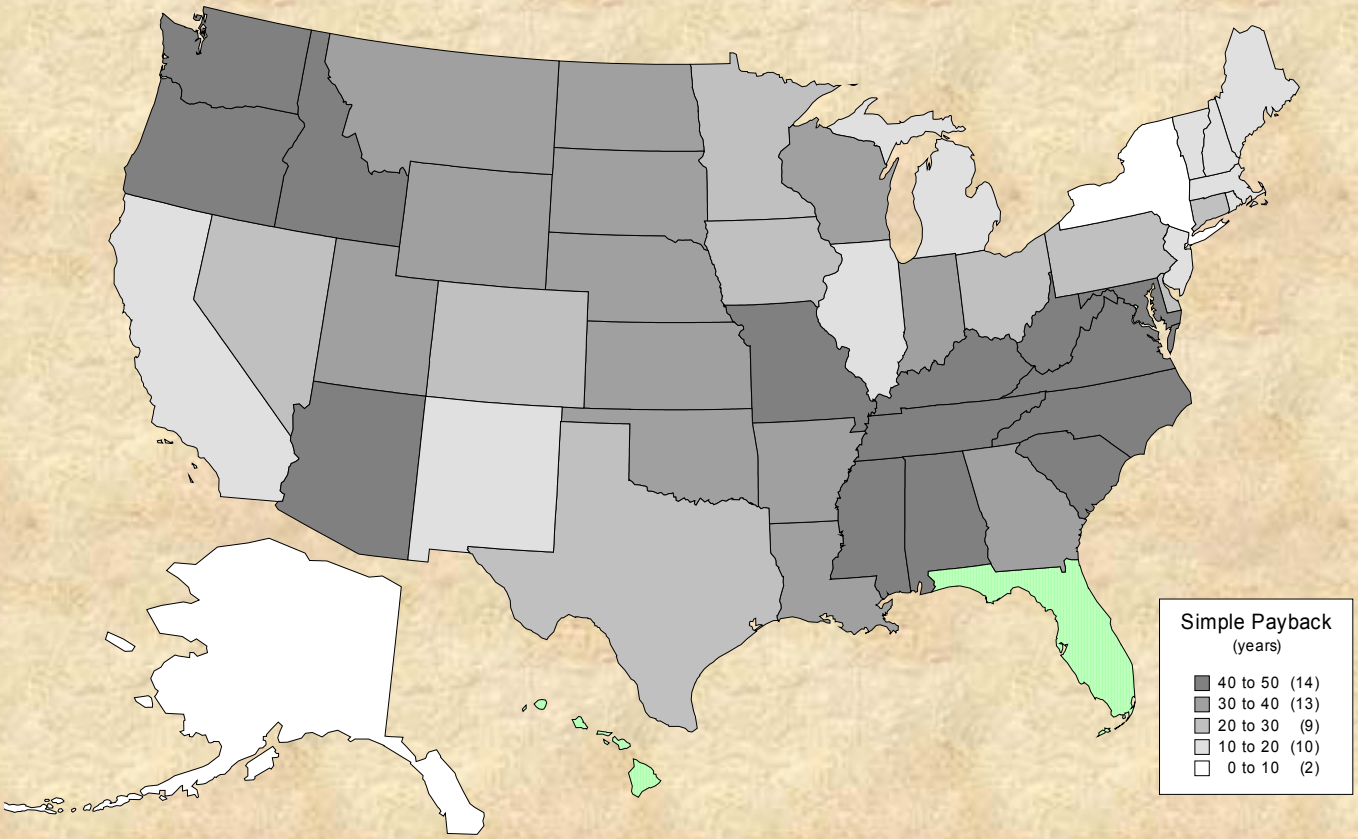
Residential Fuel Cell: Simple Payback



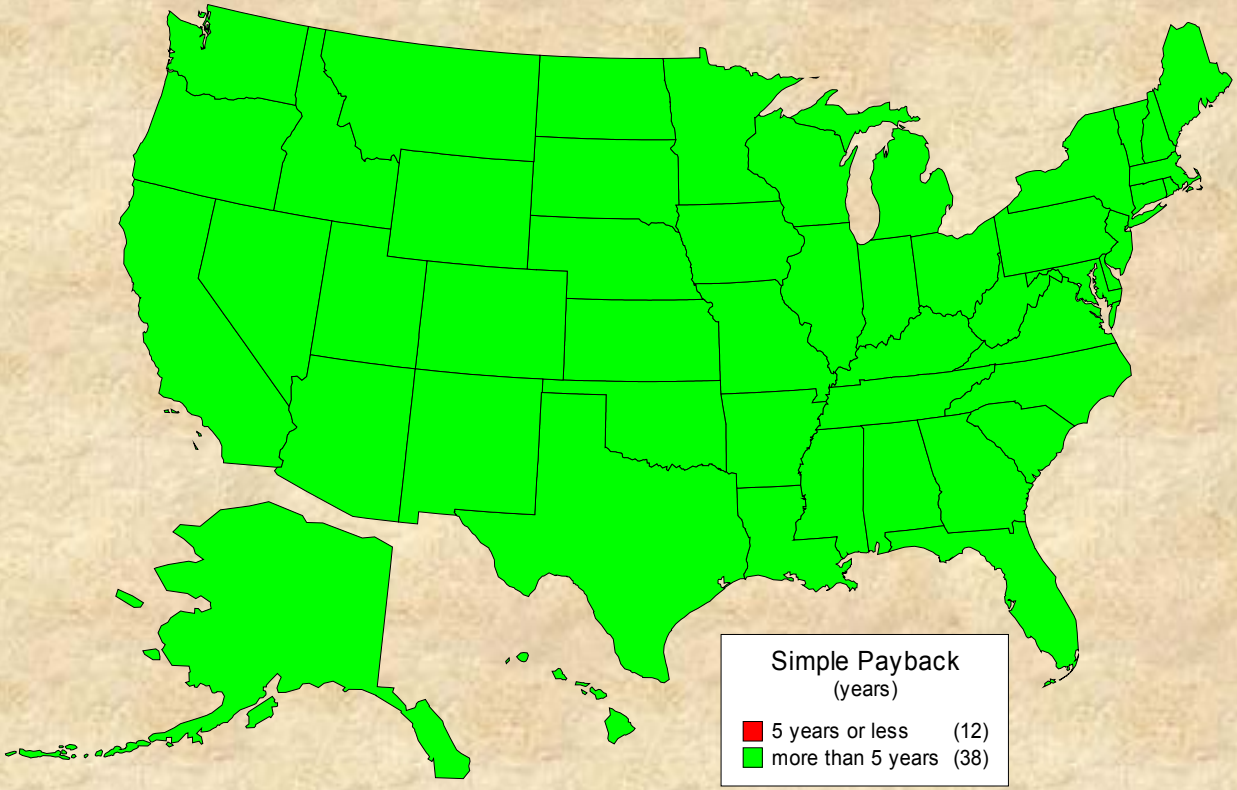
Steam Turbine Topping Cycle: Simple Payback



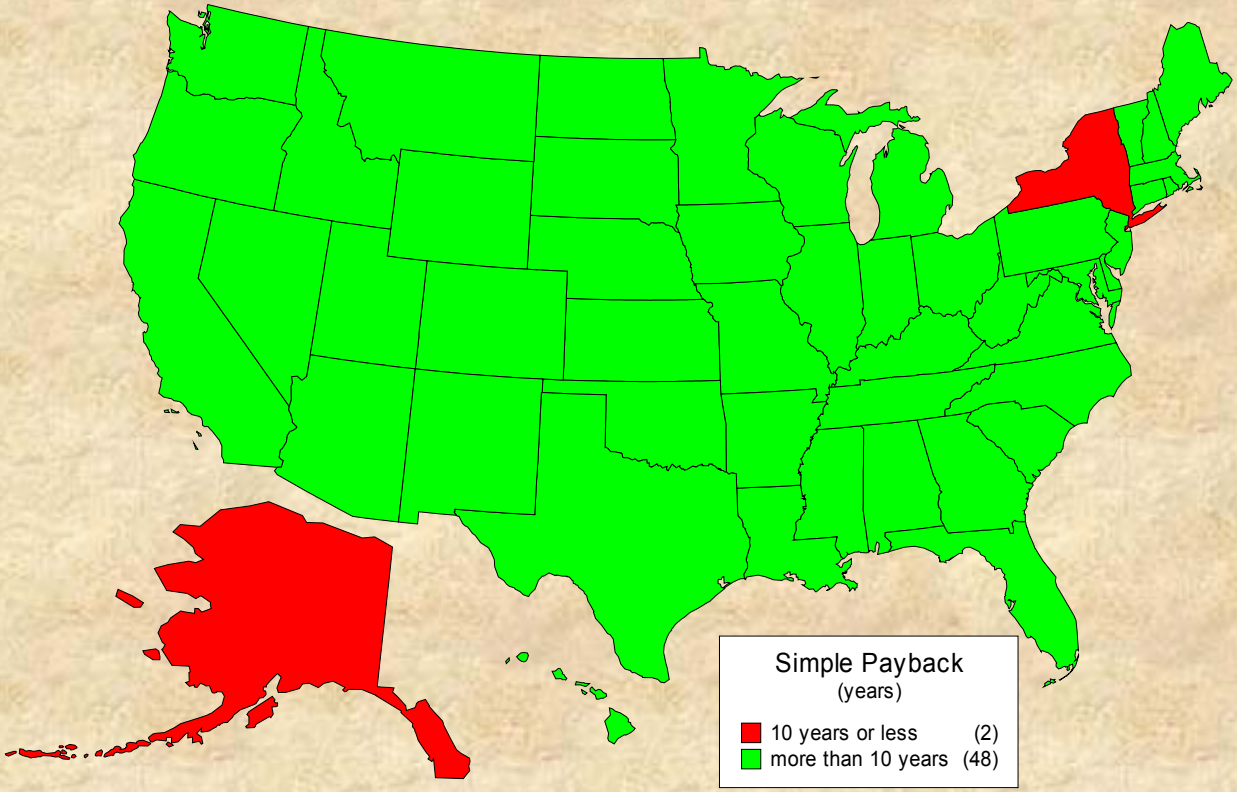
Stirling Engine Generator: Simple Payback



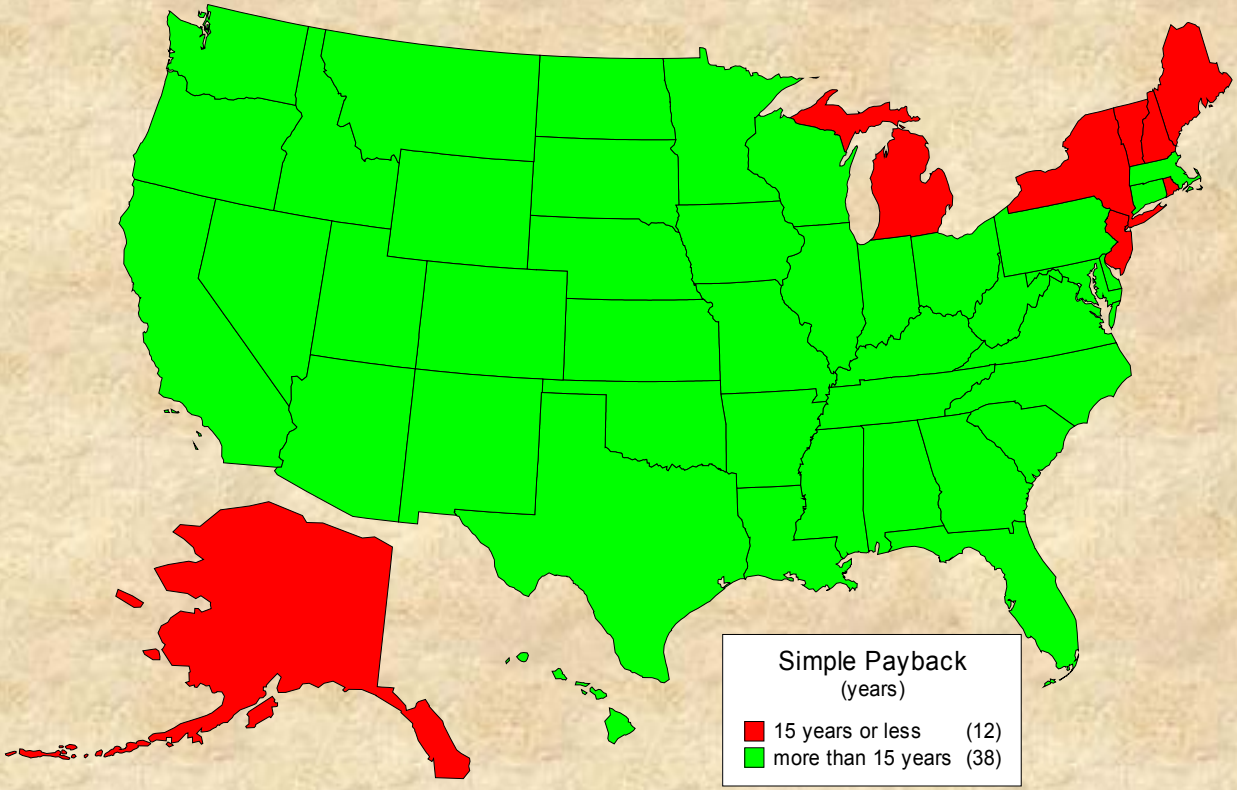
Stirling Engine Micro-CHP: 5 years or less



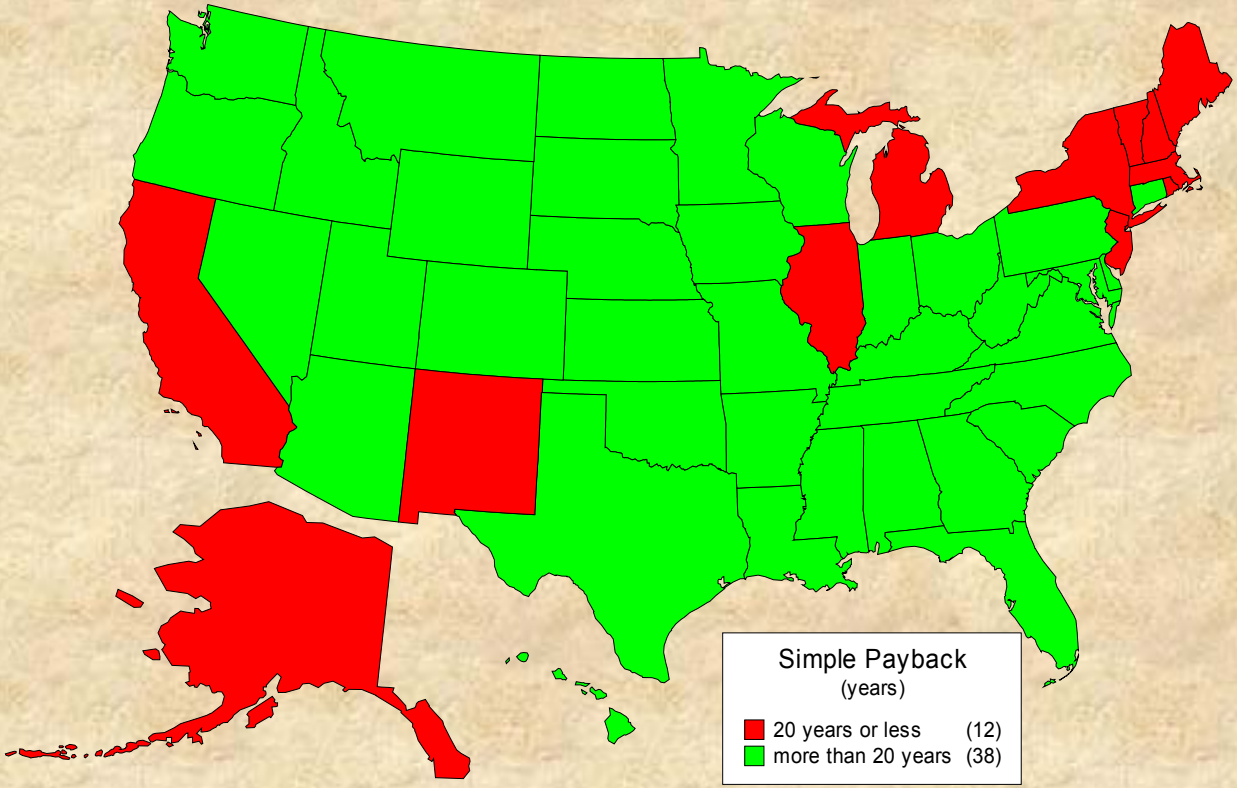
Stirling Engine Micro-CHP: 10 years or less



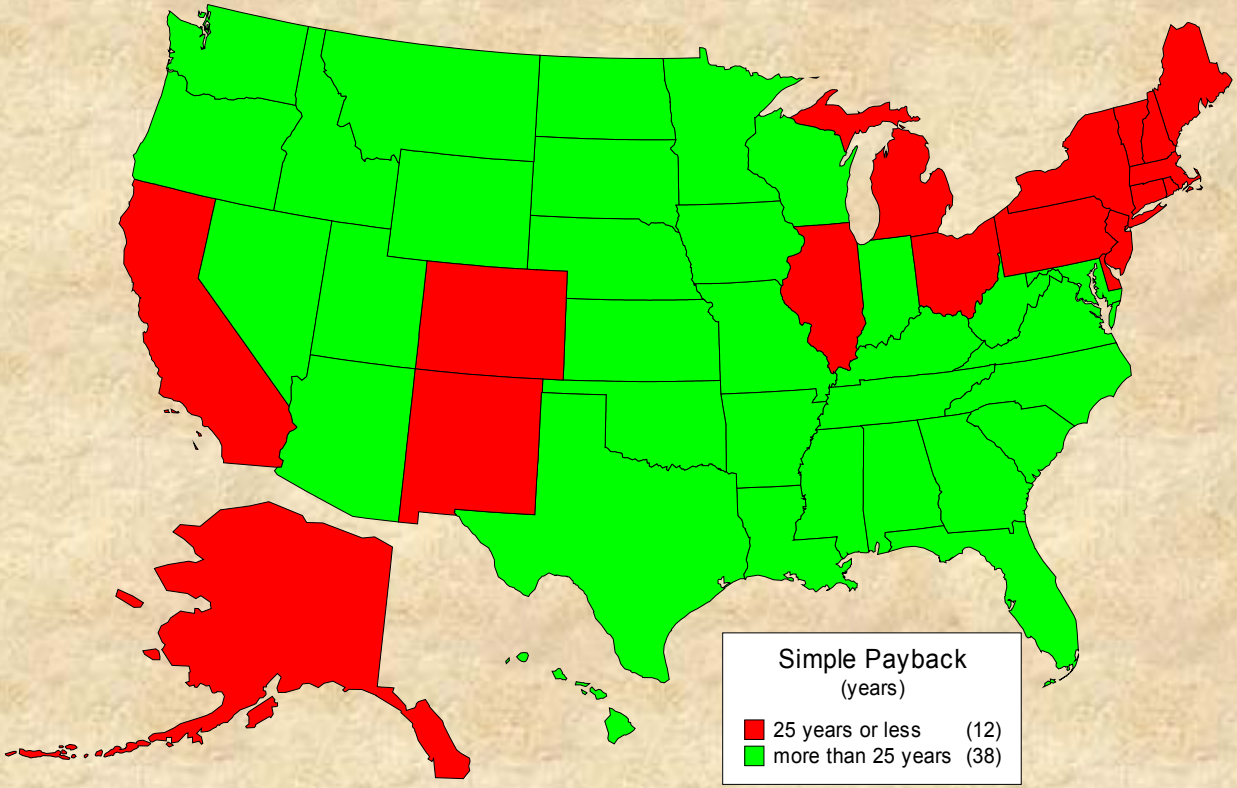
Stirling Engine Micro-CHP: 15 years or less



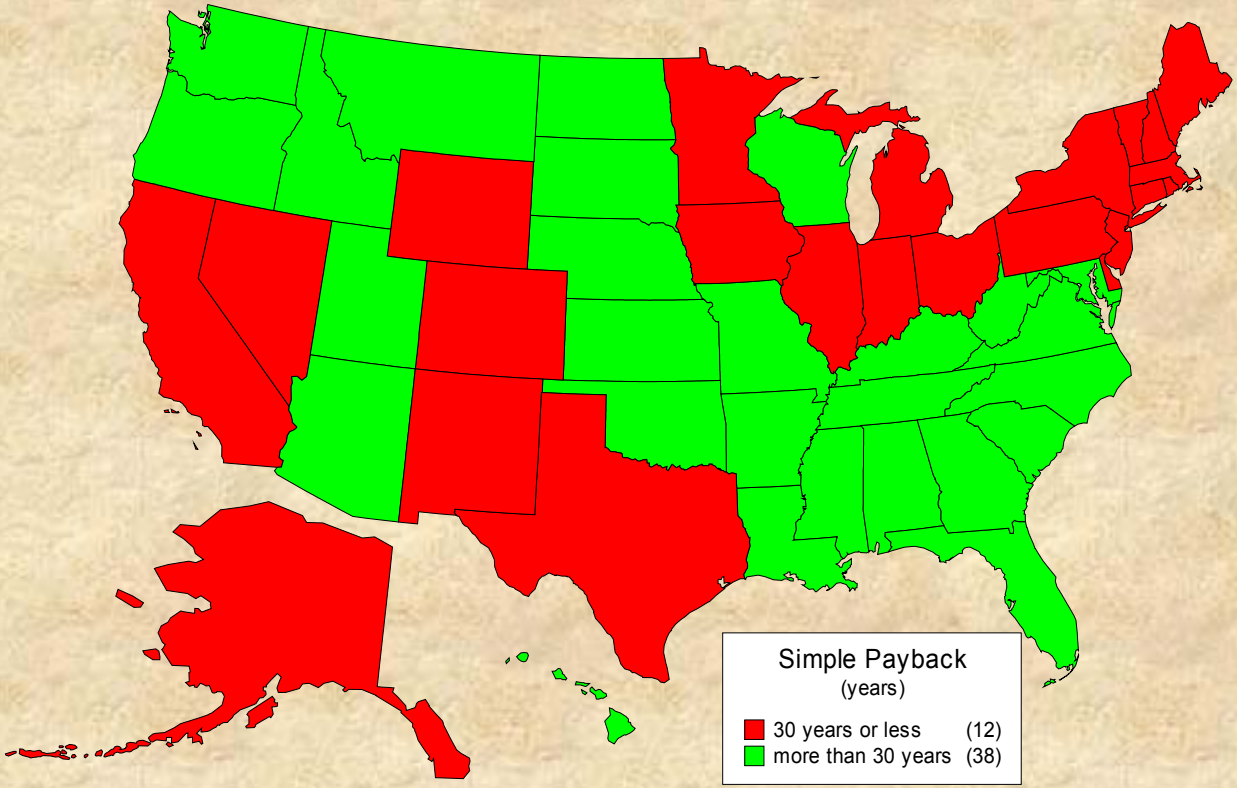
Stirling Engine Micro-CHP: 20 years or less



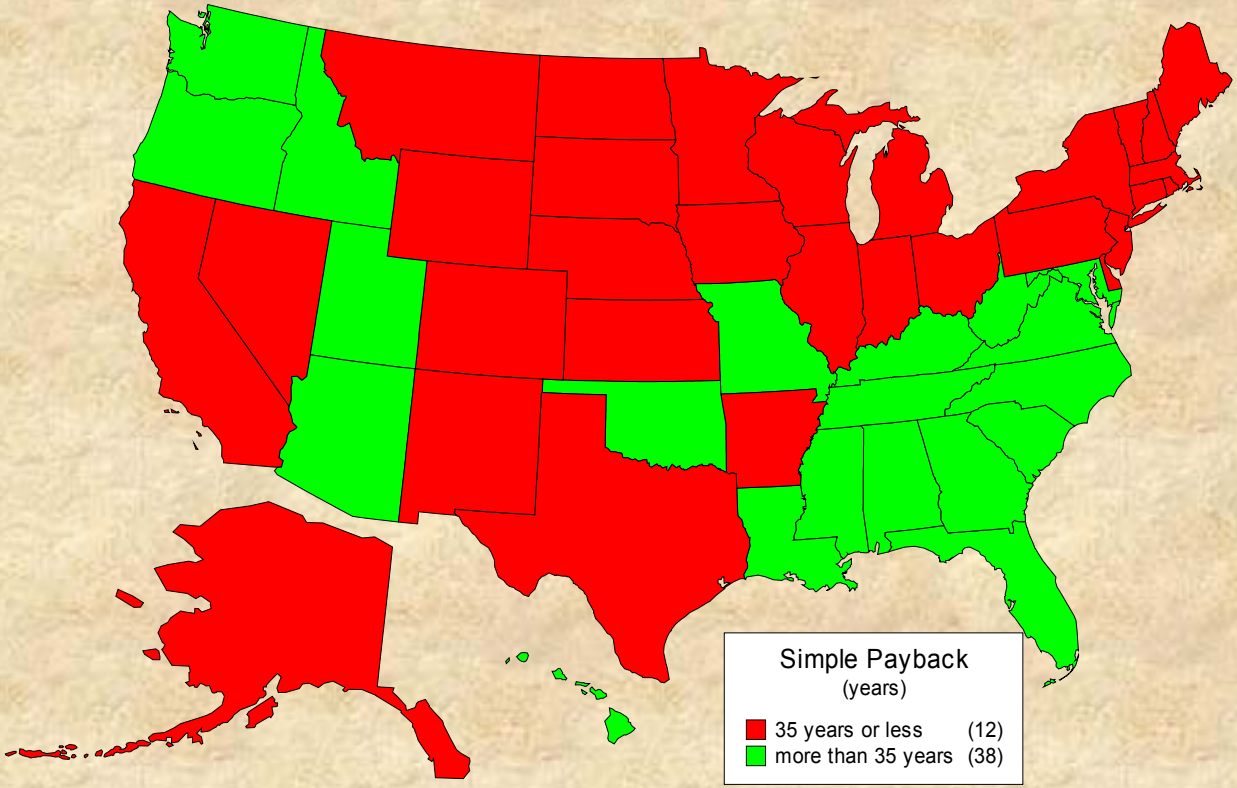
Stirling Engine Micro-CHP: 25 years or less



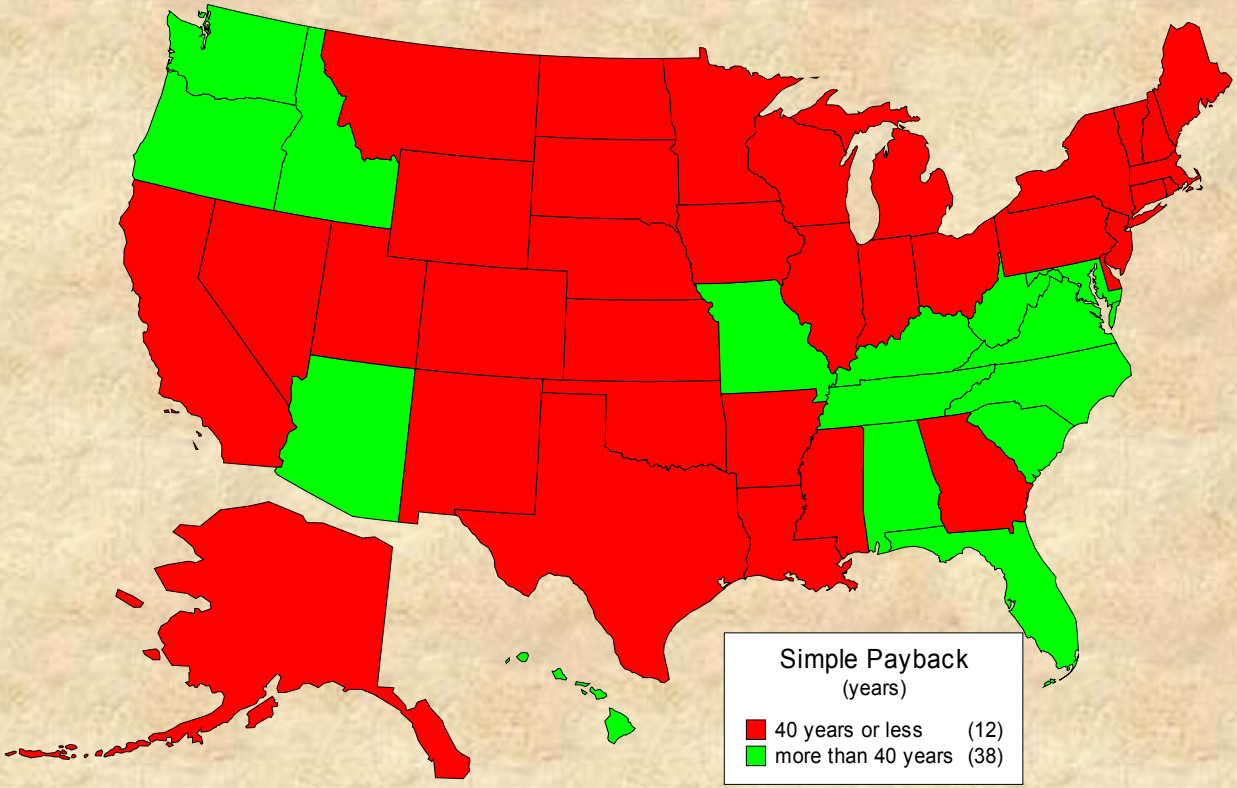
Stirling Engine Micro-CHP: 30 years or less



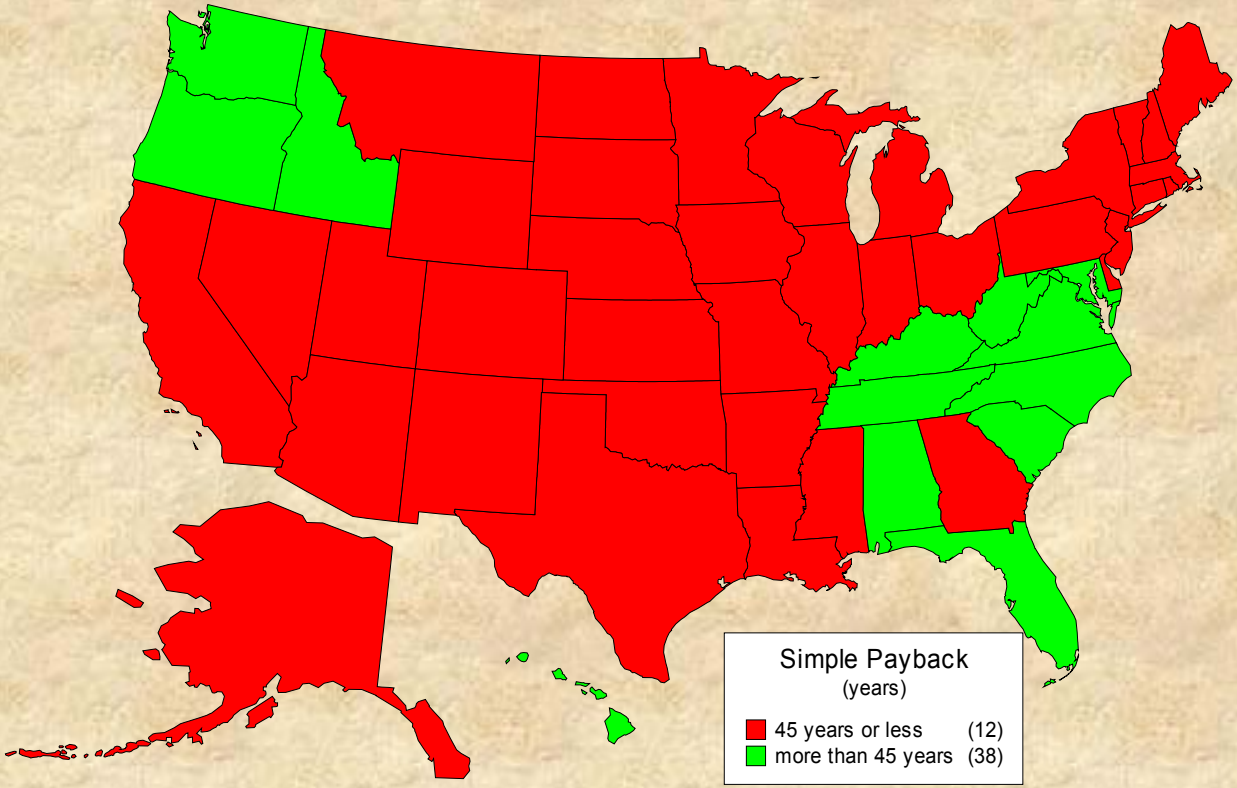
Stirling Engine Micro-CHP: 35 years or less



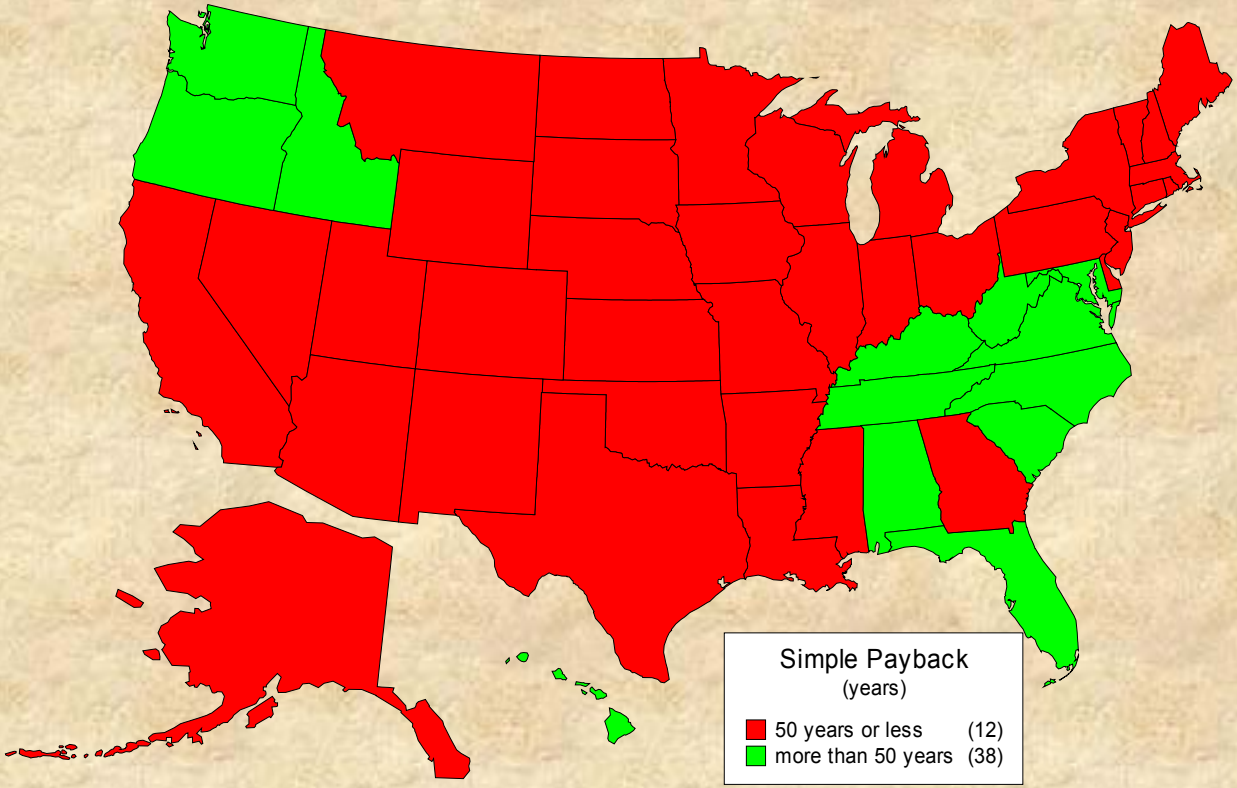
Stirling Engine Micro-CHP: 40 years or less



Stirling Engine Micro-CHP: 45 years or less

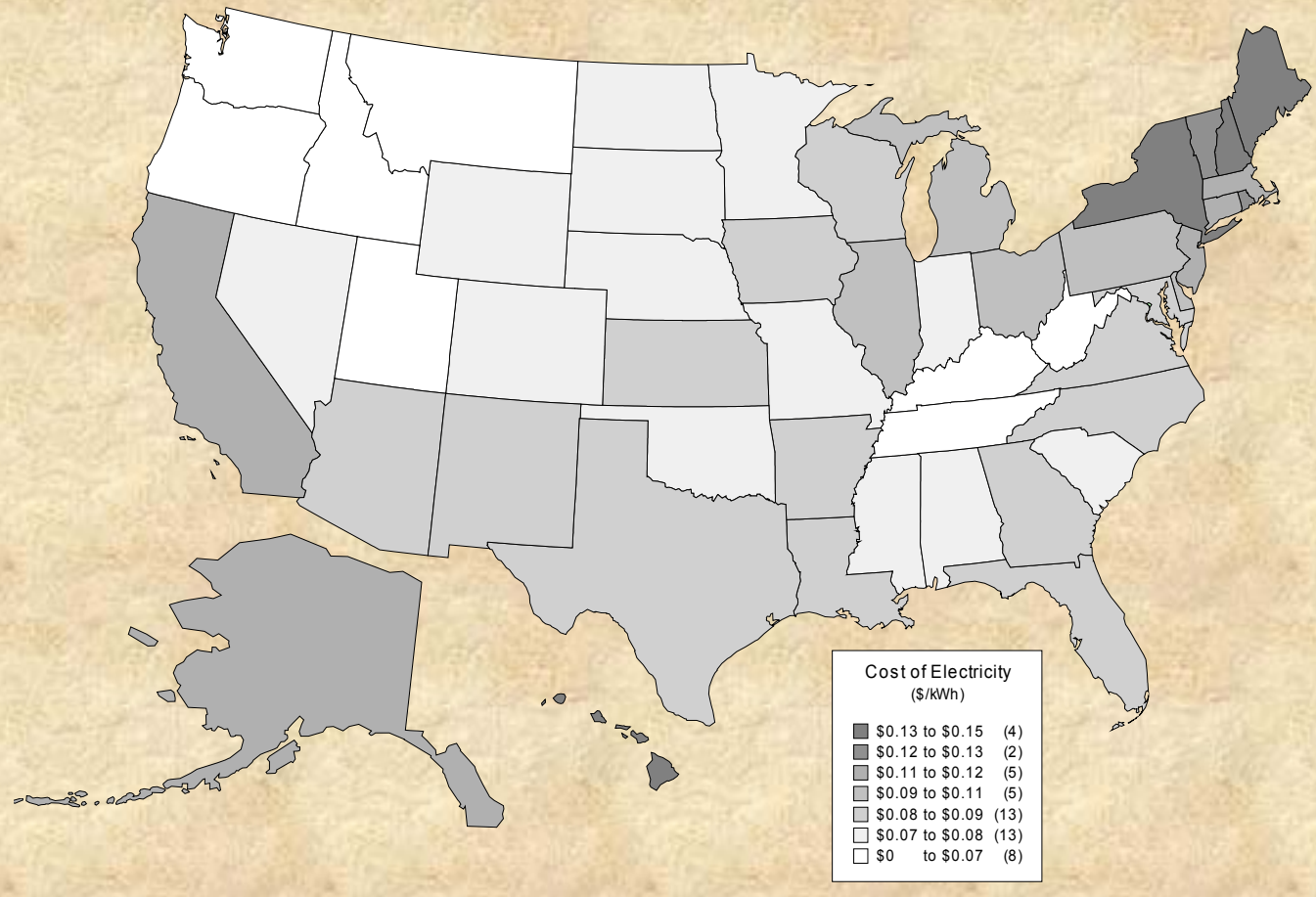


Stirling Engine Micro-CHP: 50 years or less

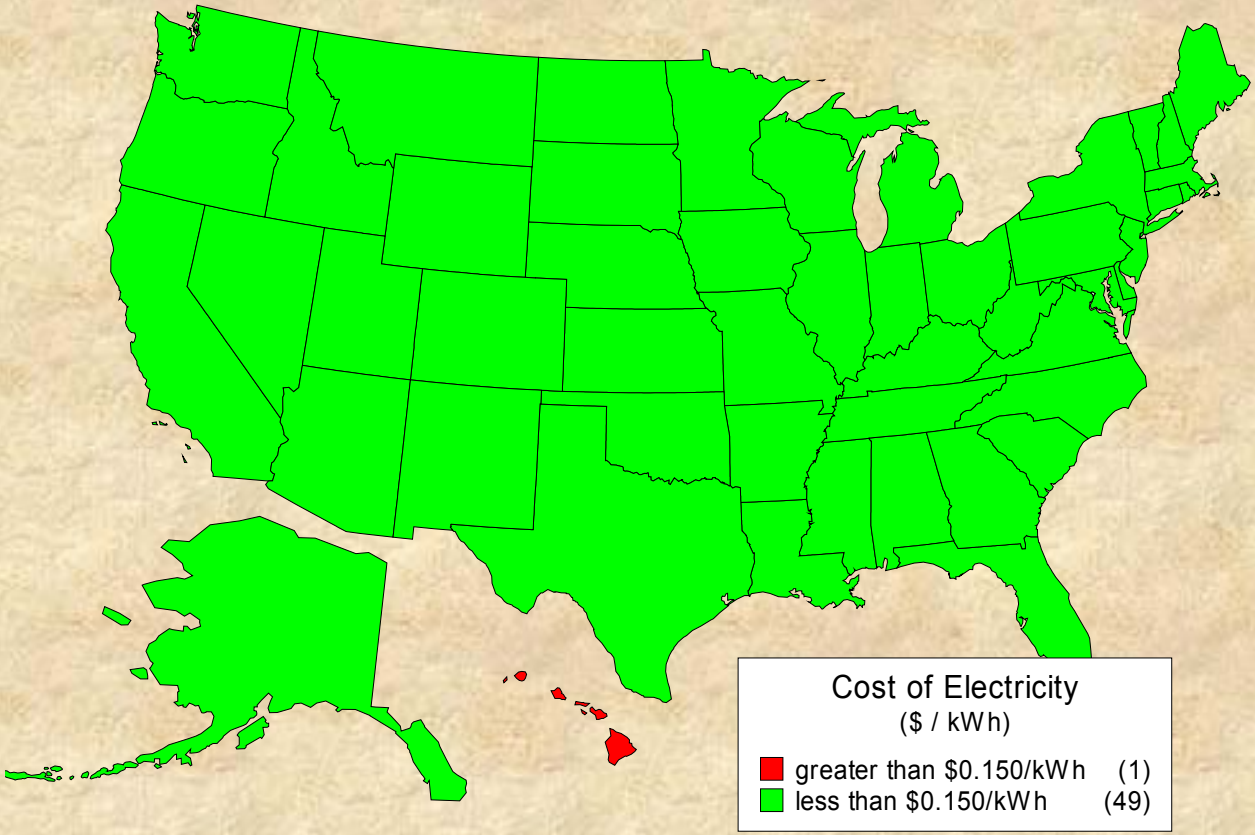


Cost of Electricity

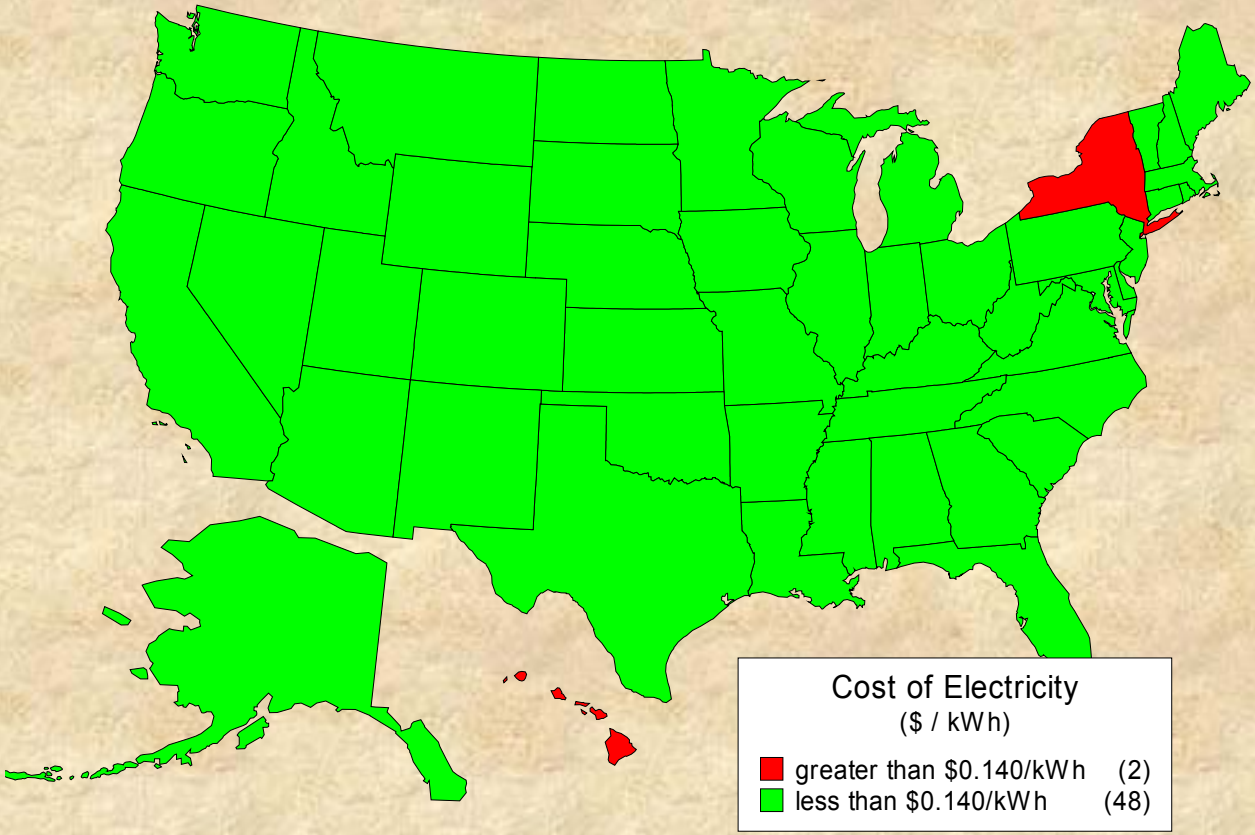
Cost of Electricity



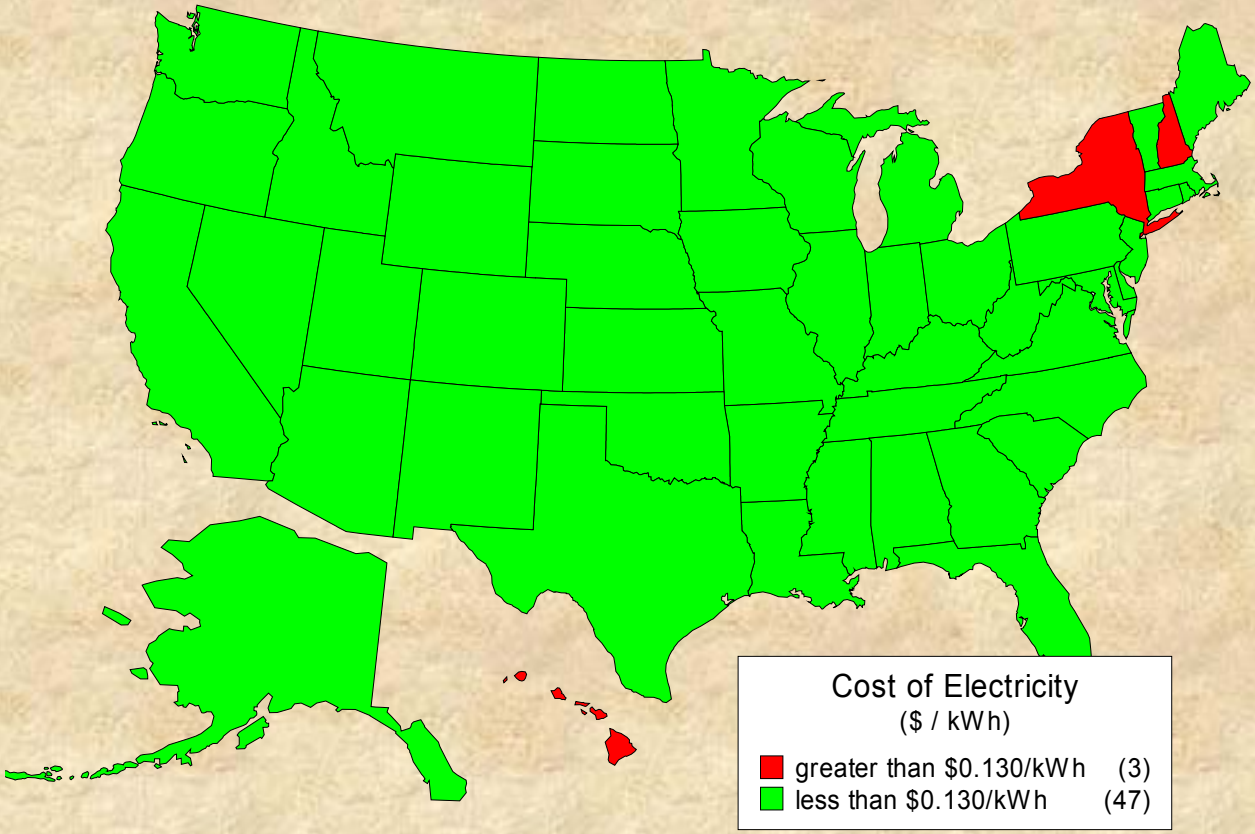
Cost of Electricity: $0.15 / kWh or more



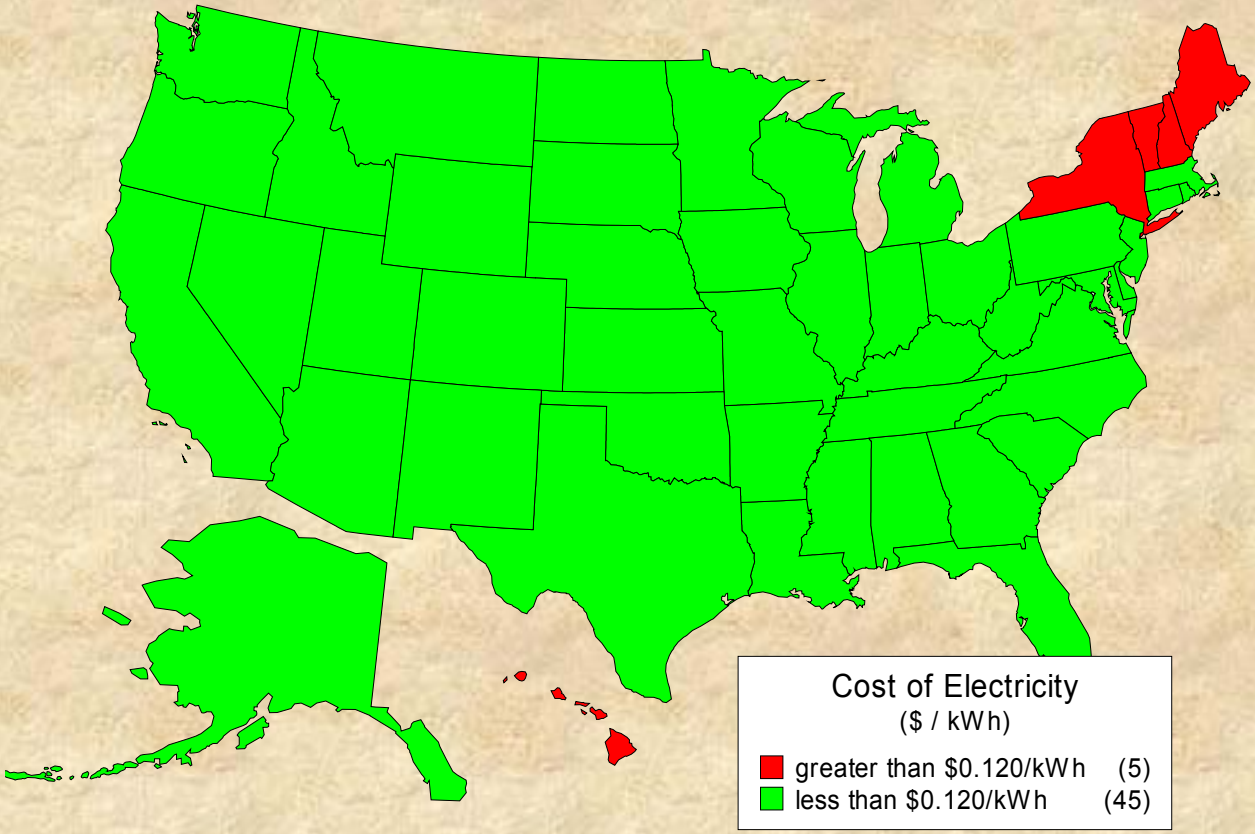
Cost of Electricity: $0.14 / kWh or more



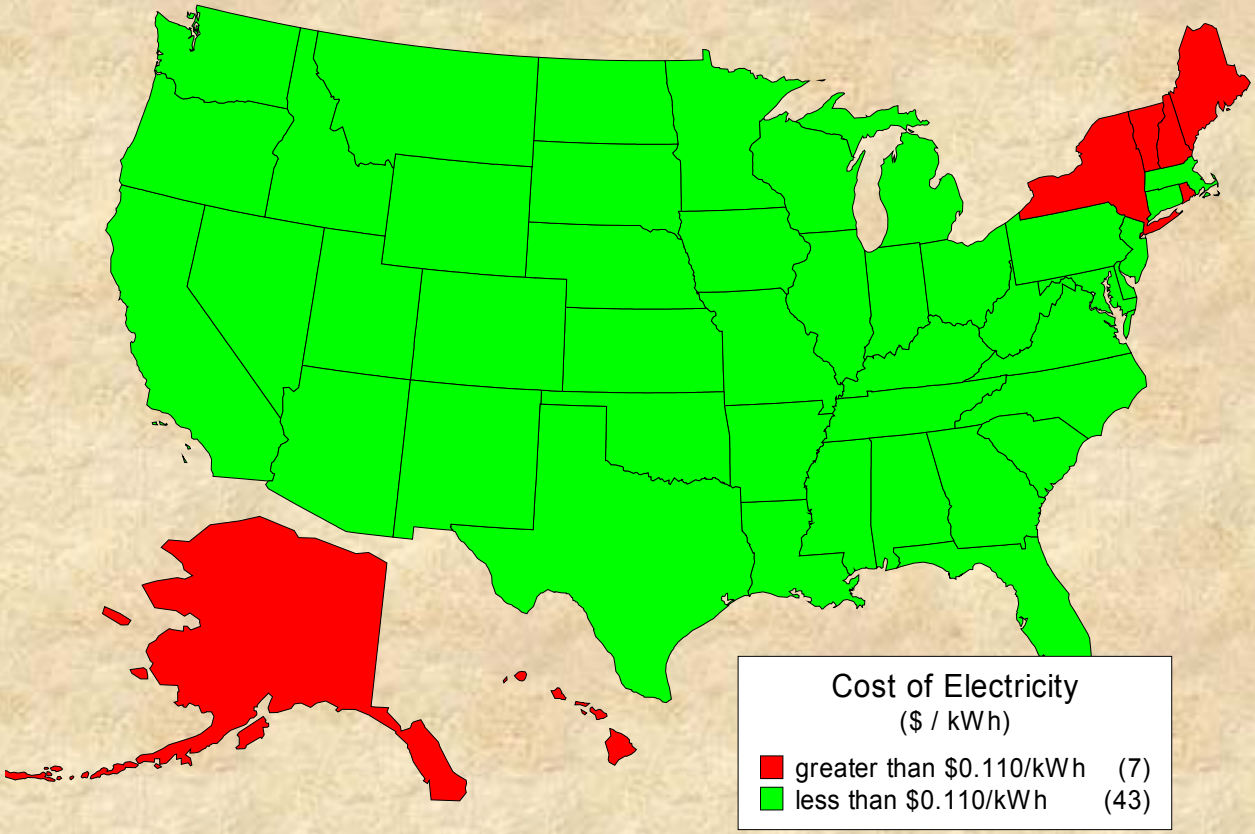
Cost of Electricity: $0.13 / kWh or more



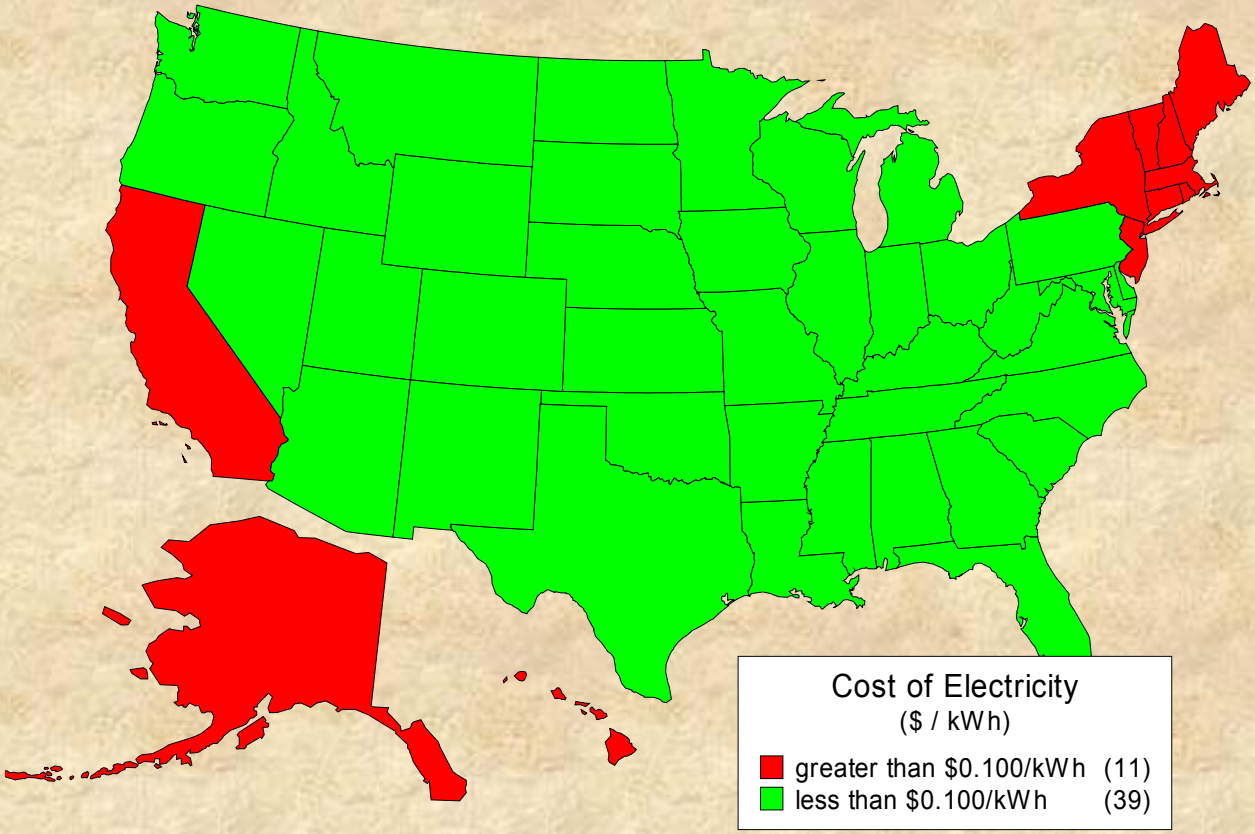
Cost of Electricity: $0.12 / kWh or more



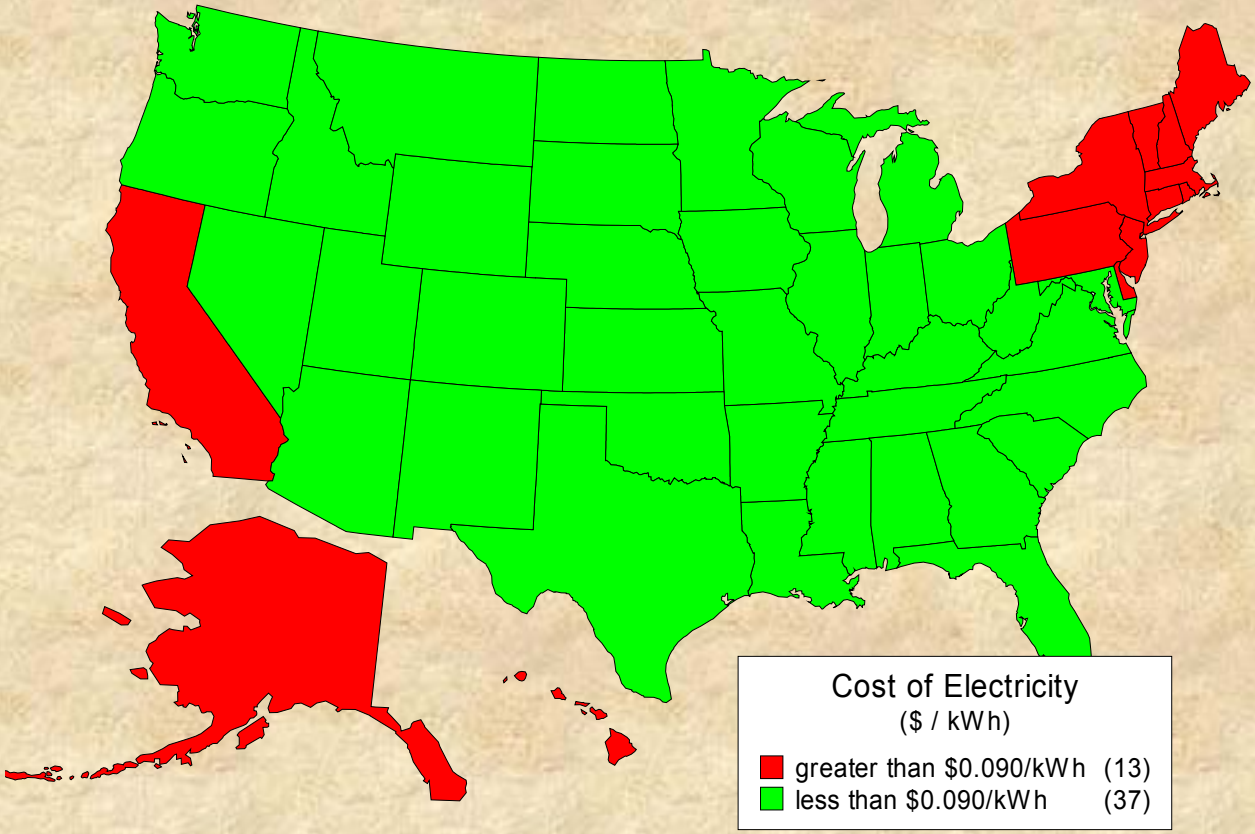
Cost of Electricity: $0.11 / kWh or more



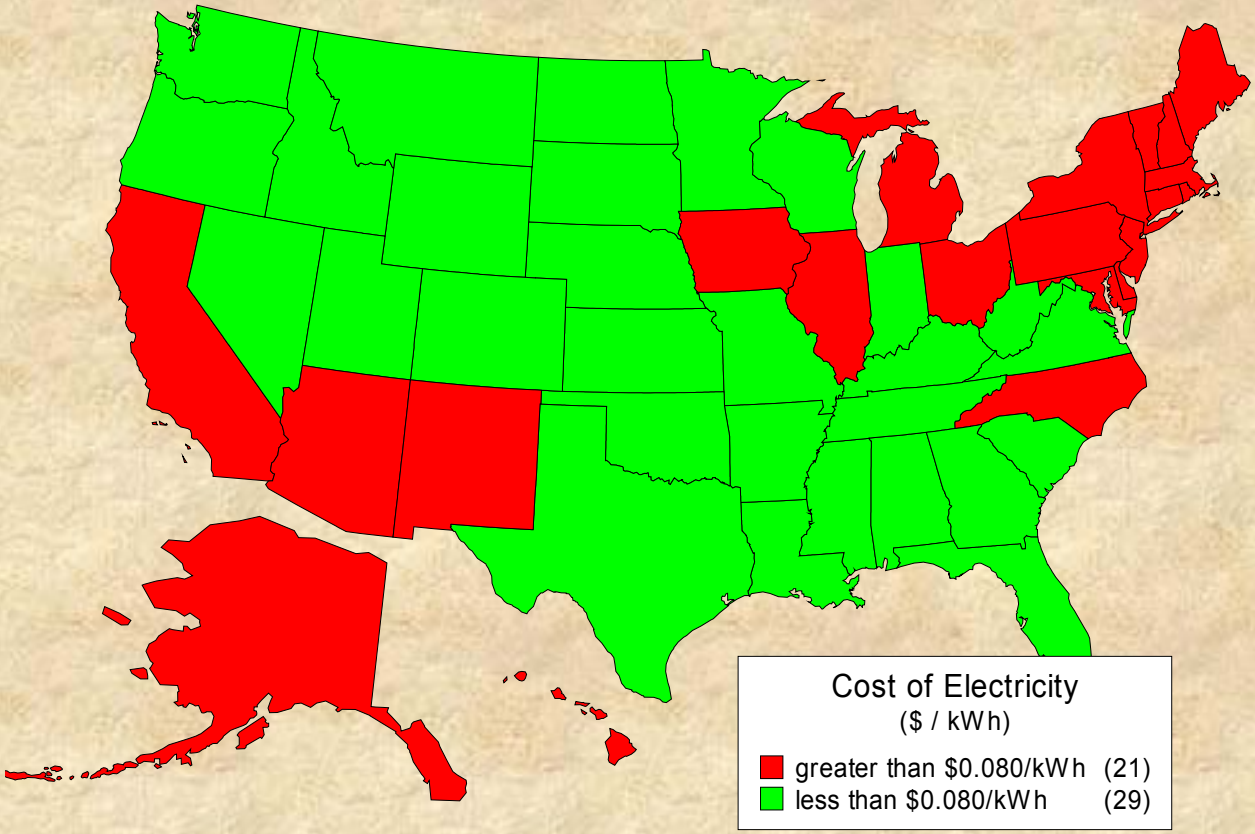
Cost of Electricity: $0.10 / kWh or more



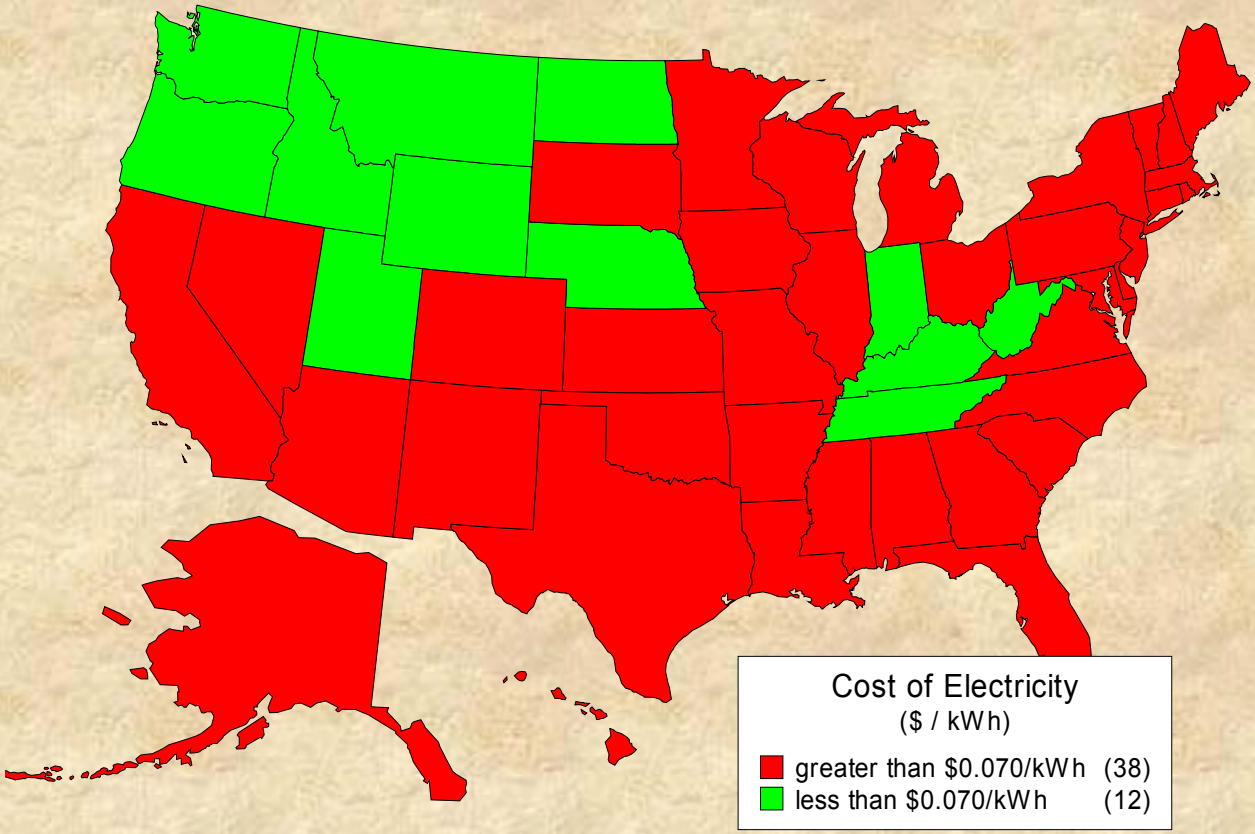
Cost of Electricity: $0.09 / kWh or more



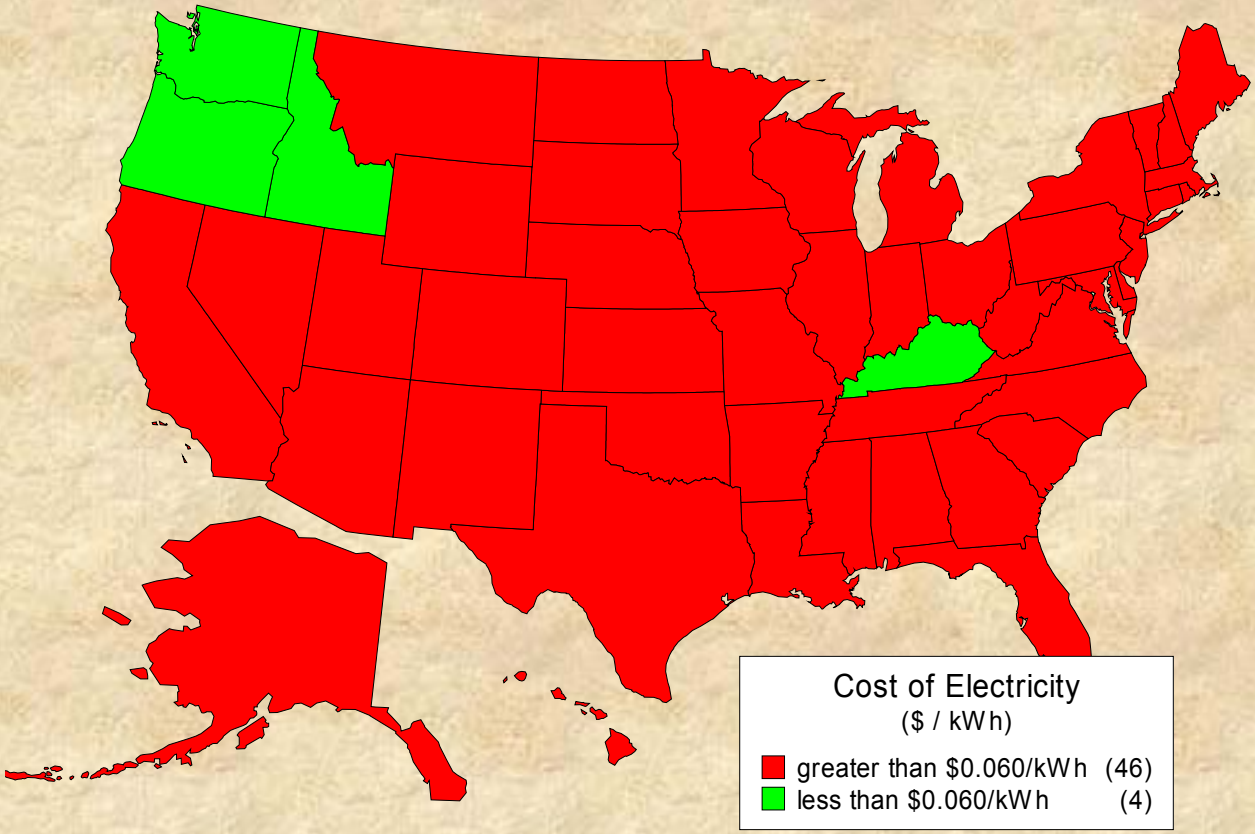
Cost of Electricity: $0.08 / kWh or more



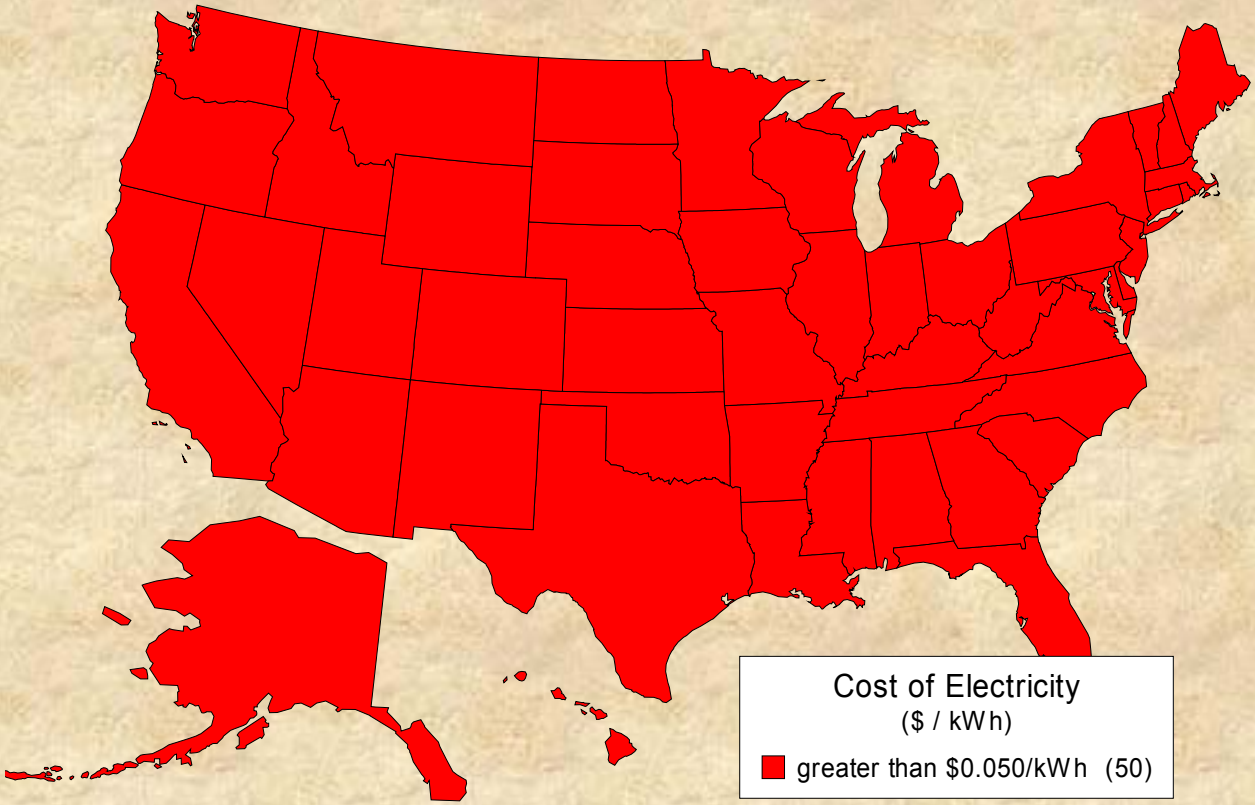
Cost of Electricity: $0.07 / kWh or more



Cost of Electricity: $0.06 / kWh or more



Cost of Electricity: $0.05 / kWh or more



Conclusions:

- Micro-CHP appears viable in some markets
  - High electric rates
  - High heating loads
- Greatest potential (simple payback under 15 years)
  - New York
  - New England States
  - Alaska
  - Michigan
  - New Jersey